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24 July 1980

USSR Report

SPACE

(FOUO 7/80)

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MANNED MISSION HIGHLIGHTS

"SOYUZ T" SPACE TRANSPORT SHIP

Paris AIR & COSMOS in French No 797, 26 Jan 80 pp 46-47

[Article by Albert Ducrocq: "The 'Soyuz T'"]

[Text] Four months have gone by since the declarations made by the Soviet cosmonauts present at the Dubrovnik Astronautics Congress, according to which the reoccupation of Salyut 6 would be seen as imminent.

The Soviets in fact felt the need to draw up balance sheets and to inquire about the status of their materiel: ever since November they have indicated that no cosmonaut flight would take place before 1980.

It is an intermediate program--aimed at testing a new material--that they decided to implement in launching "Soyuz T" on 16 December.

This Soyuz T was not manned. It is nonetheless a spacecraft designed to be manned but which, in this operation, was tested through automatic controls. Outwardly the "Soyuz T" is similar to the "Soyuz" with which we are already familiar. It has basically the same engine module and the same cabin but the equipment is different. Essentially, the Soviets have endeavored to modernize a materiel whose conception dates back to the time of the "Vostok," whose construction was started as early as 1960, i.e., 20 years ago when they resorted largely to fluid mechanics and electromechanics but at which time electronics was only at its mumbling stage. At the time, people at the most contented themselves with placing transistors on circuits which had been designed at the time of tubes. The Soviet Union had made a good start in transistor electronics. On the other hand, she was to mark time for a long time in miniaturization techniques when the small-scale, and then a fortiori the large-scale, integrated circuit came about.

Today the situation has changed: while they cannot lay claim to the immense series possessed by the Americans or to the latter's extraordinary mastery of logic, the Soviets have built excellent quality microprocessors. In creating individual microcomputers they have become known for realizations of surprising ingenuity and performance. They must have undertaken to create new equipment for their "Soyuz," in which the number of captors has apparently been increased considerably, the telemetric ratemeter having been marked up accordingly. Of course, the instrument and command panels (derived from the Vostok) have been entirely redesigned because of this.

Digital computing on the Russian spacecraft has replaced the analog apparatus of yesterday. Thus, the "Soyuz T" seems capable of calculating its trajectory in real time, thus capable of comparing its speed and position coordinates with those of the target it is aiming at, which allows it to maneuver with great flexibility.

Observers have noted that it was only after three days, at the end of its 49th orbit, that "Soyuz T" docked on 19 December with "Salyut 6" whereas in the past the station was joined by the manned "Soyuz" during the 17th revolution and by automatically controlled vehicles during the 33rd revolution. Besides the possibility of minimizing fuel expenditure, the long orbiting has made in-flight testing of the new Soyuz possible.

Soviet cosmonauts training in the Caspain Sea in view of a possible splashdown by a Soyuz

The Forward Compartment

Solar panel used to be present on the "Soyuz" transport ships for additional electric power. They had been done away with starting with "Salyut 3" (in order to gain weight) on the transport ships destined to dock with the stations. They have made their reappearance on "Soyuz T," giving the ship a great deal of autonomy.

Another innovation is the use of common fuels meant respectively for the main engines and for the orientation system. In the past the latter had to resort to the catalytic decomposition of hydrogen peroxide. But from now on it will use the same fuel, produced from hydrazine, as the main engine. Adopted very early by the Americans, this formula of a common reserve tank for all the propellants clearly points to an optimization of fuel utilization.

"Soyuz T" has docked with the station's forward docking unit which, in principle, is reserved for docking with manned spacecraft. In 1977, however, following the accident of "Soyuz 26," [sic] the first crew to occupy "Salyut 6" entered through the forward compartment. Observers saw in that operation the prelude to a new phase of exploitation of the station. After "Soyuz T" has undocked from "Salyut 6" and returned to earth at the end of a test which the Soviets have announced to be a "long" one, one must presume that a manned Soyuz will go up and take its place.

The question is: will it be a conventional "Soyuz" or will it be a "Soyuz T?" The Russian have told us that the success of the present operation "will not mean necessarily that the 'Soyuz T' would be used for the next missions." How is one to interpret this statement?

In fact, it would appear logical that the "Soyuz T" having been successfully tested, its utilization would be normal, at least in the short run, for all manned missions considering the possibilities that make it much superior over the conventional "Soyuz." It is especially important that the flight duration not be limited to two days as it was yesterday so taht if docking failed, the spacecraft would not have any option but to come down.

New Training

Nonetheless there is a practical problem: the cosmonaut teams at Zvezdnyy gorodok have been trained for the conventional "Soyuz" and not for the "Soyuz T," on which those responsible for the space programs could not afford to count before the craft has been proven flight-worthy.

How much time does adaptation to the "Soyuz T" require? From 4 to 6 months if one goes by Soviet statements. Which means that a conversion would be possible within a relatively short time. It is not certain, though, that such a conversion would be decided upon, especially in the case of Intercosmos teams: it would seem illogical to start by asking them to unlearn what they have learned so far. It is, therefore, conceivable that for the Intercosmos flights they are going to continue using conventional "Soyuz."

On the other hand, for the flight of maintenance teams, it would not be surprising that the Russians would seek to put the "Soyuz T" into use rapidly in spite of the fact that the operations would have less flexibility with two types of spacecraft.

It can very well be imagined that a "Soyuz T" would be docked at the forward docking unit of "Salyut" while the aft docking unit would receive the "Progress" spacecraft or the conventional "Soyuz" manned by visiting crews. In that case, it would no longer be a matter of one crew arriving on one craft and departing on another as has happened several times before. Otherwise, the teams would be under the annoying stress of having to change their flight habits as they change from one craft to another.

These thoughts have led us to many other questions.

The first one concerns the order in which we can expect that the five flights currently inscribed in the "Intercosmos" program for manned missions would take place in the next two years. Not long ago, we had the following sequence of cosmonaut launchings to look forward to: Hungarian, Cuban, Mongolian, Rumanian, and Vietnamese. But there are a number of indications that lead us to believe that the Vietnamese may not be the last of the series. On certain lists he figures ahead of the Rumanian. And--after the reports on his training last month--there are relatively numerous observers who believe that in the above hierarchy he may have in fact gained several places above his original ranking.

The French Cosmonaut

We wonder whether these "Intercosmos" missions which are designed to fly cosmonauts from the socialist countries would all take place before the flight of the French cosmonaut, which although inscribed within the "Intercosmos" framework will, in fact, involve a special program. All things considered, nothing is less certain. And we do not known whether the French cosmonaut will fly on board a conventional "Soyuz" or a "Soyuz T." Only one thing is certain and that is, he will not spend time on board "Salyut 6." He is excluded in any case since the exploitation with four cosmonauts on board will be continued only in 1982. But one is left in the dark as to what will be, in the case of the "Intercosmos" missions for CEMA cosmonauts, the articulation between "Salyut 6" and future stations.

To put the final touches to the "Salyut" to be used for the French flight, the Russians are waiting--it is known--to find if the selected cosmonaut would be a man or a woman. They seem quite pressed to receive this information and hopefully it could be communicated to them before the end of the month after the selection tests, which are now taking place, will be over. Thirty-seven female candidates have been registered, 10 have been retained, the medical examinations having led to the elimination of 2. We should know very soon if the physical tests would pass a "critical number" sufficient to guarantee that France would be certain to present a small female team.

The haste with which the Soviets want to know about the latest arrangements seems to reflect their desire to launch "Salyut 7" in a few months should the utilization of "Salyut 6" prove to be no longer possible--in order to prevent delays in the execution of their manned missions.

If we are to believe Konstantin Feoktistov, the "Intercosmos" program is, in fact, an "open" program: the Soviets cannot at the present time say how many crews "Salyut 6" would be able to receive, but they do intend to pursue the exploitation of their first second-generation orbital space station as long as it will prove to be materially usable.

The "Salyut" Propulsion System

Last Apring it was on an almost circular orbit at 405 kilometers from the earth, parameters ranging from 399 to 411 kilometers, when Lyakhov and Ryumin left "Salyut 6," ensuring that the station had a long lifetime without having to resort to its engines. The atmospheric drag at such altitudes in fact was minimal: it represented a modest 1 kilometer every 3 days, or 50 kilometers in 5 months. In actuality it was at some 351 kilometers from the earth that the "Soyuz T" docked with "Salyut 6" on 19 December; the trajectory correction conducted on 25 December was aimed at raising its average altitude by 25 kilometers, in other words to regain "2-1/2 months" by transferring the space complex to a 370 - 382 kilometer orbit.

It will be noted that this transfer has been executed by utilizing the propulsion system of "Soyuz T:" the spacecraft had produced a thrust of 14.7 m/s consuming some 110 kilograms of fuel. If one takes into account the 160 kilograms of fuel which had been necessary previously for the space vehicle to reach "Salyut 6" from its initial orbit (201-232 kilometers), one can see that the Soyuz T has already consumed at least 270 kilograms for maneuvers that are essentially propulsion-related. Since we know that the two-phase return of a "Soyuz" coming back from a high orbit requires some 250 kilograms, we believe that the quantity of fuel carried on "Soyuz T" would come to 600 kilograms or even a lot more.

The utilization of such a "Soyuz" as the locomotive of a space train will appear to be natural. In the past we have denounced as illogical the operation to refuel "Salyut" from a supply vehicle so that "Salyut" engines can be used for trajectory maneuvers; the vehicle docked with "Salyut" can use the fuel much more simply in order to arrive at the same result.

Nonetheless we cannot help being struck by the hesitation of the Soviets for more than one year to use the propulsion system of "Salyut 6." This system is known to have malfunctioned in 1978: last February Lyakhov and Ryumin found a station fallen to 270 kilometers above the earth. They spent much effort to repair its propulsion system, or more exactly, its tank pressurization apparatus, in the course of a very long operation which at the time was presented as a success. But never since has the propulsion system of the "Salyut" station been utilized; the orbital station has never been put back into the planned orbit. The explanation may be that even though the propulsion system has been repaired, the Soviets still entertain some doubts as to its functioning in prolonged service. They are, therefore, intending to keep the equipment in good shape for the last operation, which will consist of making the station reenter through the atmosphere over the Pacific at the end of its career.

[7-1751]

1751
CSO: 1853

COSMONAUT TRAINING FACILITIES PICTURED

Paris AIR & COSMOS in French No 808, 12 Apr 80 p 41

[Photo caption]

[Text] The Soviet press agency TASS published in April the first photographs of the "hydrolaboratory" used in the training of cosmonauts in EVA during missions with the "Soyuz" transport ships and "Salyut" orbital stations. This installation, which is a large pool in which real-scale mock-ups of the manned satellites are submerged, is service at the Cosmonaut Training Center at Zvezdnyy Gorodok near Moscow. The simulators (which are pierced to equalize pressure) are true to scale and are fully equipped (including entry hatches and transparent solar panels). The floor supporting the mock-ups is mobile. During operaticns, the cosmonauts wear their pressure suits with life support back-packs. The first photo shows (from left to right) General Georgiy Beregovoy, director of the Yuriy Gagarin Center, and General H. Kamanin inspecting the installation with the mock-ups of "Salyut" and "Soyuz" in the background. The second photo shows two cosmonauts working around the submerged "Salyut" simulator. NASA possesses a similar installation for training its astronauts.

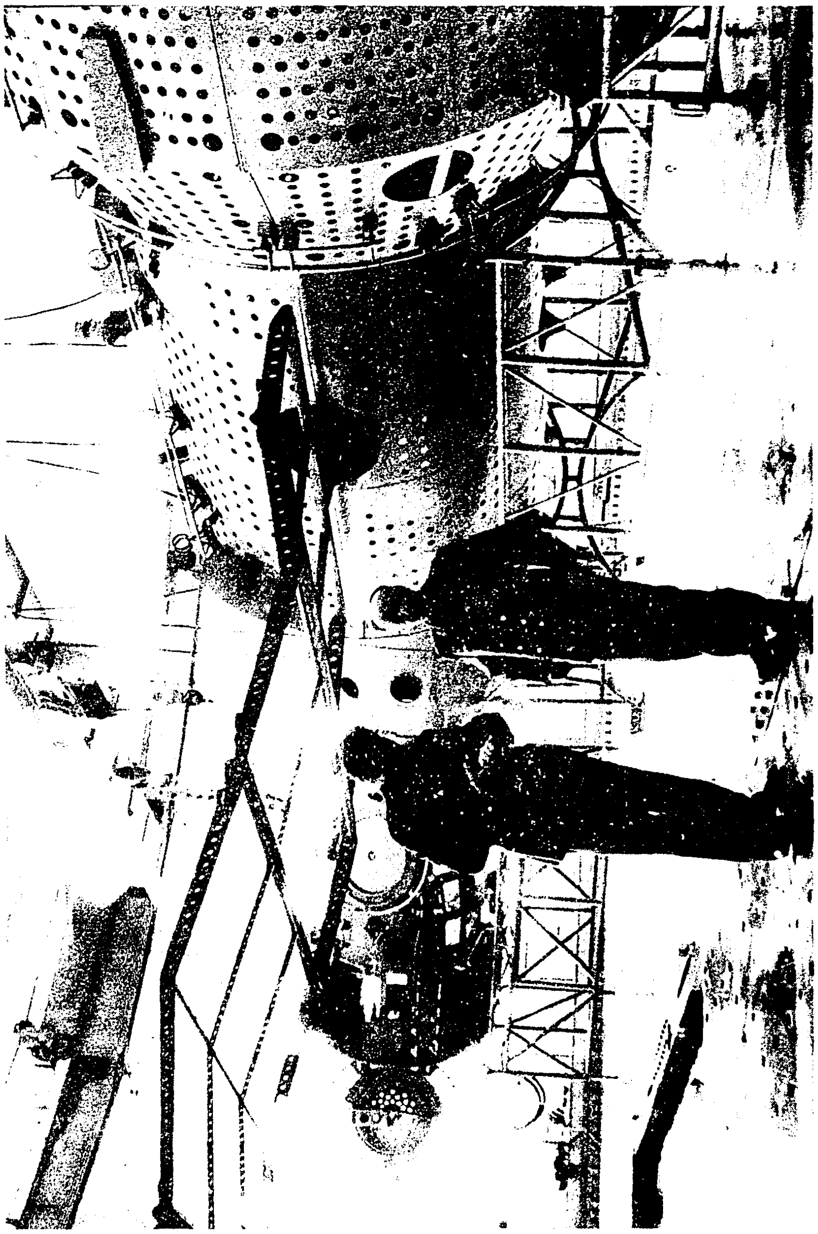

Photo 1

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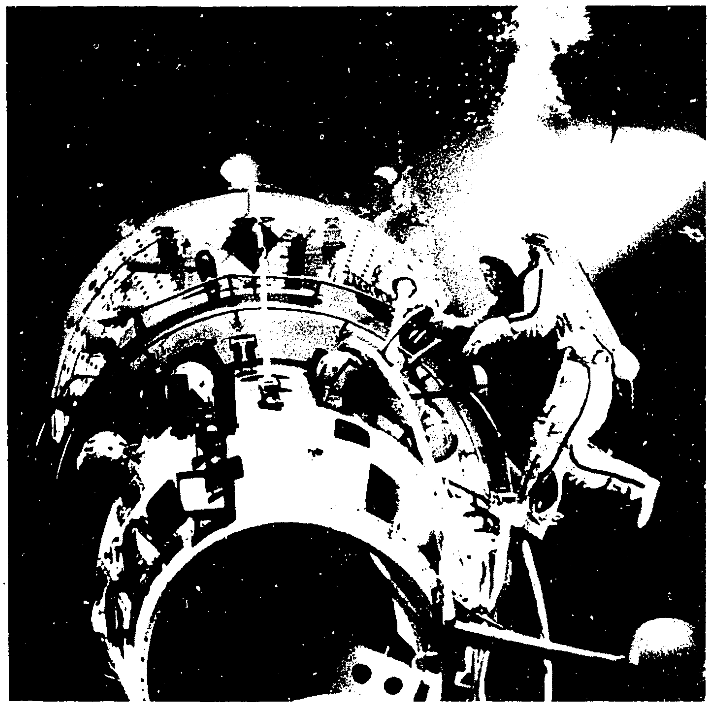
Photo 2



[10-P]

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LIFE SCIENCES

OPTICAL RESEARCH IN SPACE: CHAPTER 2. VISION IN SPACE

Leningrad OPTICHESKIYE ISSLEDOVANIYA V KOSMOSE in Russian 1979 pp 66-87
[Chapter 2 from the book by A.I. Lazarev]

[Text] Chapter 2. VISION IN SPACE

2.1. Special Features of Visual Perception in Space

Under space flight conditions, the percentage of information incoming through a cosmonaut's visual analyzer substantially increases in the overall volume of information incoming to the cosmonaut. This is explained by the fact that under conditions of weightlessness, a portion of the mechanical receptors are disabled. In particular, the proprio receptors yield distorted information on the position of the body and its individual parts; the amount of information incoming to a cosmonaut via the sound analyzer is reduced, etc. [181, 183, 187, 188].

Under ground conditions, 80 to 90 percent of all of the information perceived by a human operator arrives through the visual channel. The role of vision as a channel for the arrival of information concerning the external world increases even more for a cosmonaut. The majority of operations performed by a cosmonaut in flight are performed with the active participation of the visual analyzer. On one hand, these operations include such things as control of the angular and translational motion of the spacecraft, monitoring the readings of instruments and the operations of the spacecraft systems, and on the other hand, visual observations of atmospheric optical phenomena, and the search for, observation and identification of ground and space objects. Even such operations as moving inside the spacecraft or in open space, as well as simple acts of locomotion are performed only by means of vision. This is especially characteristic of the period of adaptation to conditions of weightlessness, when the coordination of motion has not yet been restored.

However, the assertions that "under conditions of weightlessness, not one of the indications of the sense organs, besides vision, as a rule yields correct information for orientation in space" [91], is apparently somewhat exaggerated. In space, the amount of information from the vestibule and tactile sensitivity is reduced. The information from the hearing organs remains constant, while the sensitivity can be somewhat increased by virtue of a reduction in the sound background. A person under these conditions orients himself better towards a sound source and reacts more rapidly to new sounds. The orientation toward heat sources, etc, is retained in space. On the average, one can assume that the role of all receptors in space, with the exception of vision, is cut approximately in half as compared to ground conditions. For this reason, about 10 percent of all the information incoming to a human operator is set aside for these receptors under ground conditions, so one can assume that in space, vision apparently provides a cosmonaut with about 95 percent of all of the information on the external world. Thus, the role of vision in space is exceptionally great. It follows from this that the information channel should operate quite reliably. The information on the external world incoming through the visual analyzer in space should be just as adequate as under the customary ground conditions. For this reason, any deviation of individual vision functions of a cosmonaut from the normal ground level should be treated as a disruption of the operational reliability of the visual system.

It is natural that to estimate the level of the "adequacy" of the visual information and the visual performance of a cosmonaut in flight, it is necessary to study the influence of space flight conditions on the most important functions of the visual system so that the results of these studies are used to predict the behavior and capabilities of the visual system when performing research and experiments during space flights. The main parameters of the visual apparatus which determine its servicability are the frequency-contrast characteristic, the threshold sensitivity and the inertia and function of color vision.

In line with generally accepted concepts, the process of visual perception can be conditionally broken down into two steps. The first step is related to the visual perception, in which the sensor apparatus which perceives the visual information and transmits it to the brain participates. In the second step, the information arriving at the brain is processed and analyzed, sense is made of it and it is compared with already known information. For this reason, the adequacy of visual perception is related both to the activity of the sensory apparatus and to the subsequent processing and analysis of the visual data in the cells and structures of the brain.

In studying the visual system, both stages of visual perception can be studied at the same time, but it is also permissible to study them separately, especially the stage of visual sensation. It is expedient to study the second stage, which involves the processing and analysis of visual data, following a study of the process of visual sensation, i.e., after establishing the level of adequacy of the visual perception mechanism under space conditions.

By comparing the visual apparatus of a human with the optical systems known at the present time, a number of exceptional features of the functions of human vision can be noted, the most important of which are the following:

a) The exceptionally high threshold sensitivity of vision in the visible region of the spectrum, down to 10^{-17} watts with respect to the radiative flux at the spectral sensitivity maximum of night vision for a wavelength of 510 nm;

b) The large dynamic range, on the order of 10^{10}, i.e. the ability to function under conditions of enormous changes in brightness (from 10^5 to 10^{-5} cd/m^2) and illumination;

c) A high resolving power (in some cases with a favorable brightness level, less than 1') in a rather wide field of view;

d) High contrast sensitivity (up to 10^{-2} with a favorable brightness level and angular size of the objects);

e) Rather good color differentiation (a threshold differentiation of wavelengths in the visible region of the spectrum of down to 1 nm);

f) The capability of working at maximum reliability for a long time;

g) Fast response (a time constant of about 0.02 - 0.2 sec, something which is comparatively small when considering the enormous volume of information being processed simultaneously by the visual system).

It is especially important that these exceptional qualities are combined in one visual system. An optical system with higher spatial or spectral resolution can be built, as well as with a higher threshold sensitivity with respect to illumination, but apparently it is impossible to design an optical system which possesses all of the qualities enumerated above at the same time, just as an optical system with a higher contrast sensitivity has not been successfully designed. The unique combination of such outstanding qualities makes it possible to reliably utilize the visual system as one of the most important tools for studying the natural environment from space.

It was natural to presuppose during the preparation for space flights that a deviation from normal working conditions could lead to some changes in the visual functions. In this case, it was to be anticipated that the greater the deviation of the working conditions from normal ones, the more significant would be the deviation from the visual standards and functions.

The conditions of space flight, from the moment launch until landing, differ substantially from normal conditions for human activity, including the customary conditions for the activity of the visual system. Among these conditions are weightlessness, long isolation of the crew, increased emontional stress, especially during the launch and landing of the space vehicle, specific light conditions in which the visual system operates, etc. Apparently, each of the above mentioned factors separately and all of them together have a negative impact on visual functions. However, it is altogether possible that individual visual functions change both for the better and for the worse, and for this reason, the overall influence of the various factors of space flight can promote a partial or complete compensation for the change in the individual visual functions. But an accumulation of negative changes in visual functions subject to the action space flight factors is more probable.

Specifically, the state of weightlessness can cause a loss of coordination in the motions of the eyes and a disruption of the fine motions of the eyes which are important for the recognition of small objects, as well as influence the resolving power of the eye. Weightlessness can lead to a change in the blood supply to the brain, in particular, the cortical end of the visual analyzer, the retina and other anatomical structures of the eye. A change in the blood supply should obviously have an effect on the visual functions, since in this case, the nourishment for the nerve cells changes and the processes for the restoration of the active substances and their bioelectric activity also change. The influence of the emotional factors of space flight also have a great impact on the psychophysiological mechanisms of vision. Vestibular stimulants can also be expected to have a definite influence on the vision of a cosmonaut.

The complex conditions of space flight do not as yet allow for the ascertaining the action of individual stressors on the visual function. In this regard, some of the functional indivators of vision which provide for the overall visual capability of the cosmonaut have been defined in studying the vision system. The following were chosen as these functional indicators: resolving power (acuity), contrast sensitivity under specified illumination and observation conditions, the function of color vision and a certain generalized indicator - the operative visual capability, which simultaneously takes into account the frequency-contrast characteristic of the vision system, persistence of vision and the errors committed by an operator in the execution of a given test.

2.2. Methods of Studying the Functional Indicators of Cosmonaut Vision

The procedure for studying the major visual functions of cosmonauts in flight is based on a comparison of these functions when in a space vehicle trainer, in the launch position and during space flight. A comparison of vision functions under various operational conditions of the operator makes it possible to determine the value and direction of change in the visual functions at various stages in the mission.

A study of the visual functions of cosmonauts can be made both by means of special instruments and tests and based on the results of visual observations by the cosmonauts in flight. It should be kept in mind that the results of visual observations can yield only approximate data on the qualitative nature and that they provide practically no quantitative aspects of the change in the major visual functions of the cosmonauts in flight. Nonetheless, the results of visual observations can supplement the data of objective methods of study using instruments and tests, and assist in the development of objective investigation procedures.

The assessment of the functional capability of the visual system in flight based on subjective impressions of the cosmonauts is to be made separately from the results of observations within the ship and through a window in the ship or faceplate of a spacesuit. Illumination inside the vehicle creates comfortable conditions for the functioning of the visual system of a cosmonaut. Only the sunlight coming through a porthole can sometimes change the comfort level of the illumination of individual areas inside the ship to a minor extent. The illumination inside the cabin provides for sufficient brightness under normal conditions of the signaling lights, the scales and faces of instruments and control equipment, as well as sufficient illumination of the operating positions and stations within the ship (as a rule, the illumination conditions can be adjusted by the cosmonaut). The sources of illumination within the cabin do not create blinding highlights and bright sources in the field of view of the cosmonauts and provide for favorable opportunities for normal operation in flight. This is why the results of observations inside the ship can be used to study the impact on the visual functions of such spaceflight conditions as weightlessness and emotional stress. For this reason, the majority of objective procedures for the study of visual functions in space is based on the observation of tabular or instrument tests by the cosmonaut inside the cabin of the vehicle.

Observations through a porthole or the faceplate of a space suit differ in the extraordinarily wide range of variation in the spectral energy, spatial and timewise characteristics of the irradiation of objects and backgrounds, the presence of light flashes from the glass surfaces of portholes and individual parts of the space vehicle. The condition of the glass of portholes (dirty, fogged or frosted up) also exerts a significant influence on the observational results, something which not only reduces the transparency of the portholes, but also sharply increases the brightness of the artificial background produced by the scattered radiation of the portholes.

The results of visual observations by cosmonauts obtained during the first space flights yielded a large volume of information of a qualitative nature on the state of individual visual functions. Observations from space of the color of the earth's surface, the atmosphere, as well as the nighttime, twilight and daytime horizons of the earth made it possible to draw the conclusion that the color vision function remains practically constant, while the contrast sensitivity function of vision in space changes insignificantly.

On the night side of the earth, in the absence of scattered radiation from the portholes, cosmonauts reliably observed stars all the way down to the fifth stellar magnitude (5^m). All cosmonauts reliably recognized stars and constellations on the night side of the earth.

Unfortunately, the results of observing stars and other weakly shining objects on the day side of the earth have as yet been interpreted insufficiently strictly. In paper [188], the specific features of observations of stars are related to an inadequate accounting for visual adaptation to light or darkness. It is underscored in this case that the time for total dark adaptation amounts to 50 to 60 minutes. The conclusion is drawn from this that during the flight time on the night side of the earth, the vision of a cosmonaut is not completely adapted, and for this reason, he will not be able to observe stars of the fifth to sixth stellar magnitude ($5 - 6^m$). However, in this case the influence of the artifical background radiation produced by the scattered radiation of the portholes is not considered. Moreover, it exerts a decisive influence on the ability to observe stars on the day side of the earth. The brightness of the scattered radiation of a porthole depends on the condition of the glass surfaces and the orientation of the porthole with respect to the strongest illumination sources: the sun, the surface of the earth and the dense layers of the atmosphere. It is specifically for this reason that cosmonauts have come up with differing estimates of the capabilities of observing stars on the day side of the earth.

Objective procedures for investigating the visual functions of cosmonauts during flight were based on the utilization of test objects. For reliable prediction of the capabilities of a crew under space flight conditions, it was necessary to make measurements of visual light and contrast sensitivity, visual acuity, V, at a specified level of illumination and contrast, the time threshold for visual perception, τ, and to compare them with the results of ground measurements in order to solve the problems related to the use of the vision apparatus. In this case, the error of a single measurement during flight was not to exceed ± 20 %.

Studies of visual acuity under ground conditions were performed by means of a standard hatch marked test pattern with 25 groups of lines. The various groups have a differing number of hatch marks, N, per millimeter. In one group, consisting of four hatch marked squares with the marks in different directions, the number of hatch mark lines per millimeter is the same. The size of the test pattern, d, was taken as 19.2 mm for an observing distance, 1, of 275 mm. The angular dimension of the light gap or the dark line of the n-th group of hatch marking lines of the test pattern was equal to the following, expressed in angular minutes:

$$d = \frac{3438}{2\,1\,N_n}$$

Then the visual acuity is:

$$V = \frac{2\,1\,N_n}{3438} \qquad (2.1)$$

A test pattern with 12 groups of hatch mark lines was designed for a study of the cosmonauts' visual acuity in flight. The visual acuity measurement error in flight amount to about ± 20 %.

A study of the vision contrast sensitivity during space flight was performed by means of a special test pattern, containing 70 circles which were split in half; each half had a different reflectivity. The angular size of the small circles when observed from a distance of 250 to 300 mm was 1.5 to 2°. The contrast between the halves of the circles varied from 0.01 to 3 where the contrast was computed from the formula:

$$K = \frac{B_1 - B_2}{B_2} \tag{2.2}$$

where $B_1 \geq B_2$ are the brightnesses of the halves of a circle. Some of the circles had a contrast of zero. The error in the determination of the threshold contrast proved to be ± 20 %.

Visual inertia was determined on the basis of recording the time an operator worked with various tests. The time expended by the the operator to count the number of hatch marks in various groups of test pattern markings was measured for this purpose. The time expended in working with a contrast sensitivity test pattern was also measured.

Test tables with hatch marked patterns were also used to determine the *operational visual capability* of the cosmonauts. The operator was to find those elements of the test pattern in which he count the number of hatch mark lines. The operational visual capability, $K_{\text{работ}}$, when working with a hatch marked test pattern was determined on the basis of three recorded parameters: the work time on a test, t_n, the frequency of the hatch markings selected for working on the test pattern, N_n, and the number of errors committed when counting the hatch markings, n_n. The operational visual capability was computed from the formula:

$$K_{\text{работ}} = 1 + \frac{1}{3}\left(\frac{t_{n\Phi} - t_n}{t_{n\Phi}} + \frac{N_n - N_\Phi}{N_\Phi} + \frac{n_{n\Phi} - n_n}{n_\Phi}\right), \tag{2.3}$$

where the subscript "Φ" indicates the parameters for ground (background) conditions (i.e., in the space vehicle trainer, or the laboratory).

Studies of the *color vision function* were made by means of a special test pattern consisting of six colored strips (purple, blue, yellow, light blue, red, green) arranged alongside black and white photometric wedges. During a flight, the cosmonaut was to determine the field of the black and white wedge, which he subjectively perceived as having the same brightness as each colored strip. The change in the perception of the subject colors ΔB_λ was determined from the formula:

$$\Delta B_\lambda = \frac{1}{6}\sum_{i=1}^{i=6} \frac{\bar{B}_{\lambda\Phi i} - \bar{B}_{\lambda i}}{\bar{B}_{\lambda\Phi i}}, \tag{2.4}$$

where $\bar{B}_{\lambda\Phi i}$ and $\bar{B}_{\lambda i}$ are the average values of the subjective brightness of one of the six colors under ground conditions and during flight respectively.

Then the average subjective brightness of the six selected colors under flight conditions is

$$B_\lambda = B_{\lambda\phi} + \Delta B_\lambda, \tag{2.5}$$

where $B_{\lambda\phi}$ is the average subjective brightness of the six colors under ground conditions ($B_{\lambda\phi} = 100\%$).

An attempt was undertaken in paper [188] to derive a generalized criterion, by means of which one can estimate the visual capabilities of a cosmonaut, taking into account the changes in the individual visual functions. The expression for such a criterion, called the *function of vision*, Φ_v, similar to the expression for the operational visual capability is:

$$\Phi_v = \Phi_{v\phi} + \Delta\Phi_v, \tag{2.6}$$

where $\Phi_{v\phi}$ is the background value of the vision function, while $\Delta\Phi_v$ is defined by the formula:

$$\Delta\Phi_v = \frac{1}{6}\left(\frac{V - V_\phi}{V_\phi} + \frac{V_{\Delta\phi} - V_\Delta}{V} + \frac{K_{\text{пор.}\phi} - K_{\text{пор}}}{K_{\text{пор.}\phi}} + \right.$$
$$\left. + \Delta B_\lambda + \frac{\Delta\bar{n}_0}{\bar{n}_{0\phi}} + \Delta\bar{t}_{\text{раб}}\right), \tag{2.7}$$

where V_Δ is the reduction in the complexity of the test pattern chosen by the cosmonaut for the counting of the hatch mark lines as compared to the threshold test pattern; $\Delta\bar{n}_0$ and $\Delta\bar{t}_{\text{раб}}$ are respectively the mean arithmetic value of the relative increase in the number of errors committed by the operator and the mean arithmetic value of the relative increase in the time he worked on all of the tests used for the background and for the operator working conditions being studied; $K_{\text{пор.}\phi}$ and $K_{\text{пор}}$ are respectively the background and the measured value of the threshold contrast.

2.3. Some Results of Studies of the Major Visual Functions Under Space Flight Conditions

Visual Acuity

Studies of visual resolving power by objective methods were started with the first flights of the "Voskhod" space vehicles. Studies of visual acuity were carried out on the 5th-6th orbit, and for B.B. Yegorov and V.M. Komarov at the start and conclusion of the mission as well. The results of the studies on the "Voskhod" vehicles showed that the visual resolving power of all the cosmonauts remained practically unchanged. A slight drop in visual acuity (by 5 - 10%) did not go beyond the limits of the error in the adopted study procedure. The results of research performed by the crews of the "Soyuz-4" and "Soyuz-5" vehicles generally confirm this conclusion. The average reduction in visual acuity did not exceed 10%. In this case, a drop in visual acuity was observed for three cosmonauts of the "Soyuz-4" and "Soyuz-5", while it increased almost by 20% for one cosmonaut.

Operational Visual Capability

Studies carried out in the "Voskhod" and "Soyuz" space vehicles showed that operational visual capability is markedly reduced during space flight. The visual capability was estimated from the results of measurements of the work time on a test, based on the complexity of test patterns selected for counting the marking lines and based on the number of errors committed. During the flight of the "Voskhod" and "Voskhod-2" vehicles, the operational visual capability of four cosmonauts dropped an average of 10%: P.I. Belyayev, A.A. Leonov, B.B. Yegorov, V.M. Komarov.

The results of the selection of test pattern complexity obtained during the flights of four space vehicles are interesting from the viewpoint of operational visual capability. The crew of the "Voskhod" reduced the complexity of the test pattern selected for counting marking lines an average of 31%, the crew of the "Voskhod-2" by 23%, G.T. Beregovoy by 9% during the flight in the "Soyuz-3", while the crews of the "Soyuz-4" and "Soyuz-5" vehicles reduced this complexity an average of 8%.

The reduction in the level of the operational visual capability is apparently explained by the fact that under conditions of weightlessness, not only the coordination of motions is disrupted, but also the coordination of the group of eye moving muscles. Under conditions of weightlessness, the force of them for changing the point of fixation proves to be excessive, because of which, it is as if the gaze "jumps over" the requisite point. This phenomenon is particularly marked when observing small objects. This phenomenon is not observed when observing larger objects.

Visual Contrast Sensitivity

Studies of Visual Contrast Sensitivity were carried out by the crews of the "Soyuz-4" and "Soyuz-5" space vehicles. The results showed that during the flight time of the "Soyuz-4" and "Soyuz-5", visual contrast sensitivity dropped by 16%, while the time expended to complete a test increased by more than 30% as compared to the time expended on similar work under ground conditions. During the study on the "Soyuz-4" and "Soyuz-5" vehicles, the visual contrast sensitivity decreased monotonically during 50 orbital revolutions, and no kind of trend towards a transition to a stable functional was ascertained.

Color Vision

Studies of the color vision function were carried out on the "Voskhod-2", "Soyuz-3", "Soyuz-4" and "Soyuz-5" space vehicles. The studies performed on the "Voskhod-2" showed a marked reduction in the subjective brightness of colors observed by the cosmonauts - by an average of 25%. The greatest reduction in the subjective brightness was observed when determining the brightness of purpose, light blue and green colors, and somewhat less in the case of red. The reduction in the brightness of the remaining selected did not exceed 10%. When performing color tests under space flight conditions, an increase in the brightness of the test colors was not noted even once. During the flights of the "Soyuz-3", "Soyuz-4" and "Soyuz-5" vehicles, the color vision function likewise underwent marked changes. Under space conditions, a stable drop in the brightness of the tested colors by an average of 20 to 25% was noted under space conditions for the crews of the "Soyuz-4" and "Soyuz-5" vehicles. An especially marked change was observed for the colors of purple and red. Based on the results of observations of seven cosmonauts - A.A. Leonov, P.I. Belyayev, G.T. Beregovoy, V.A. Shatalov, B.V. Volynov, A.S. Yeliseyev and Ye.V. Khrunov - the average values of the drop in the subjective brightness of the six colors were determined during space flight. This reduction proved to be the most pronounced for purple: it reached about 48% with respect to the background reference level. For red, the reduction amounted to 28%, 24% for green, 19% for light blue, 7% for dark blue and about 5% for yellow. The average drop in the subjective brightness was about 22% for the six colors.

2.4. The Dynamics of the Variation in Visual Functions During Space Flight

Objective (test) studies under space flight conditions have shown a simultaneous change in all of the visual functions being studied. Especially marked changes in visual functions were observed during the first few days of a mission during the Ist - 17th orbits during the period the cosmonauts adapted to space flight conditions. In the subsequent phase of the flight - the stable performance phase - the changes in the visual functions were reduced, but did not reach the preflight level. But one of the most important visual functions - contrast sensitivity - which was studied during the flight of the "Soyuz-4" and "Soyuz-5" vehicles did not reach a stable state, but continually deteriorated.

Data on the crews of the "Voskhod", the "Voskhod-2" and the "Soyuz-3, 4, 5, 6, 7, 8 and 9" vehicles were utilized for the analysis of the dynamics of the variations in the visual functions during space flight. Some 15 cosmonauts participated in the studies. The duration of the "Soyuz" missions proved to be sufficient for the analysis of the dynamics of the change in the visual functions as a function of time. The most pronounced in visual functions are observed early on during the first two to three days of the mission. In this case, the visual functions during the first days of the mission are reduced to 5 to 30%, and then a restoration of the visual functions is observed and they approximate the preflight values, something which is apparently evidence of presence of some adaptation or compensation mechanisms in the organisms of the cosmonauts. Beginning at 40 to 50 orbital revolutions, the influence of other factors begins to have an impact on the process of the restoration of visual functions, where these factors again cause a reduction in the visual functions which achieves its most pronounced value during the 70th - 80th orbits. Subsequently, a repeated improvement in visual functions is observed, which is apparently more stable than in the period between the 30th and 60th orbits of the flight. The visual function (2.6) is shown in Figure 2.1 as a function of

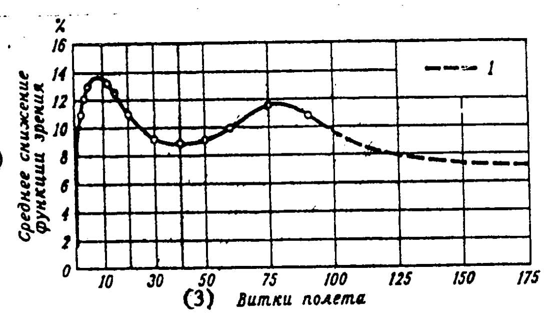

Figure 2.1. The dynamics of the average reduction in the generalized visual function as a function of the space mission time (average data for the missions of the "Voskhod" and "Soyuz" space vehicles) [188].

Key:
1. $p < 0.8$;
2. Average reduction in visual function;
3. Number of orbits of the flight.

the mission time based on the data of the crews of the "Voskhod" and "Soyuz" space vehicles. The visual acuity, contrast sensitivity and operational visual capability are shown in Figure 2.2 as a function of the duration of the space mission. It can be seen from a comparison of the functions depicted in Figures 2.1 and 2.2 that the presence of two maxima in the curve of Figure 2.1 is due to the fact that the maximum reduction in the operational visual capability is observed during the first days of the mission, while the maximum reduction in the visual contrast sensitivity is observed in the 5th - 6th days. Visual acuity changes little as a function of mission time.

The contrast sensitivity undergoes the most substantial change during space flight. The maximum reduction in the contrast sensitivity recorded in a number of flights occurs in the fifth day of the flight and amounts to about 40%, while a reduction of 10% begins practically immediately after the transition to the state of weightlessness.

Measurements of the visual contrast sensitivity were started with the flight of the "Soyuz-3" space vehicle. Because of the considerable practical importance of this characteristic and its relationship to visual acuity and the frequency-contrast characteristic, the cosmonauts in a number of space missions (the "Soyuz-4, 5, 9") were presented with test tables with hatch marking test lines having different contrasts with the background. This made it possible to carry out studies of the visual acuity at different contrasts. Where the contrast is defined by the formula

$$K = \frac{B_\Phi - B_0}{B_0}, \qquad (2.8)$$

where B_ϕ is the brightness of the background between the test lines, B_o is the brightness of the dark test lines, then $K \approx 30$ for test pattern markings with a high contrast and $K \approx 0.3$ for a test pattern with a low contrast. It was ascertained in the study of visual acuity using these test patterns that for test subjects with normal vision, the visual acuity determined from low contrast test patterns proved to average 23% less than

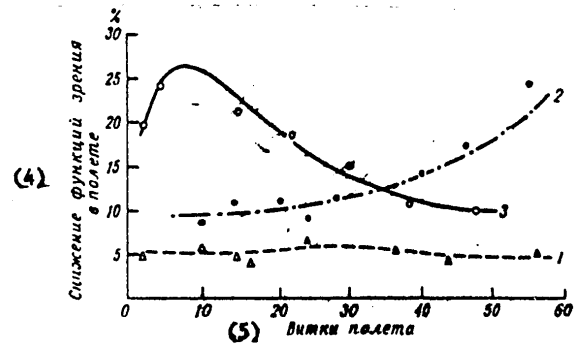

Figure 2.2. The dynamics of the major visual functions as a function of the space mission time [188].

Key:
1. Visual acuity;
2. Contrast sensitivity;
3. Operational visual capability;
4. The reduction in visual functions during the mission;
5. Number of mission orbits.

the visual acuity determined from high contrast test pattern lines. Studies of visual acuity using test patterns with different contrasts were performed by A.G. Nikolayev during the 23rd orbit of the "Soyuz-9" space vehicle. Prior to the flight, his visual acuity based on patterns with high contrast lines was $V_1 = 1.36$ and based on patterns with low contrast lines, it was $V_2 \approx 1.05$. In the 93rd orbit of the flight, when measured using the same patterns, $V_1 = 1.11$ ($\Delta V_1 = -18\%$) and $V_2 = 1.01$ ($\Delta V_2 \approx -4\%$). Thus, during the mission, visual acuity determined from high contrast test patterns changed more markedly than when determined from low contrast patterns. At the same time, the results obtained during the missions of the "Soyuz-4" and "Soyuz-5" revealed practically an identical reduction in visual acuity for hatch marked test patterns of different contrasts by about 10%.

Results of measurements in the "Soyuz-4" and "Soyuz-5" vehicles made it possible to come to some conclusions concerning the change in the frequency—contrast characteristic of vision under space flight conditions. It was noted that a reduction in the contrast sensitivity of about 2% corresponds to each percentage point drop in the visual acuity. The proposal was made on this basis that under space conditions, visual acuity falls off little during an entire mission, while the contrast sensitivity is markedly reduced.

We shall now deal with the dynamics of the change in the operational visual capability during space flight, taking into account the change in visual acuity, the contrast sensitivity and the ability of the cosmonaut to count small objects. A change in the operational visual capability is observed from the very start of a mission. As early as the second orbit, it drops by almost 20%, and by the 8th-10th orbit, this reduction reaches a maximum value of about 26%. Then there is a gradual increase in the level of operational visual capability, which proves to be about 10% below the standard level by the 40th-50th orbits.

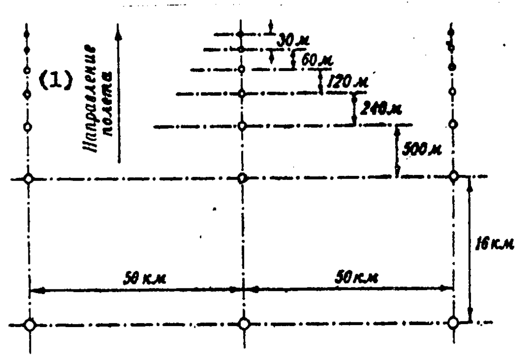

Figure 2.3. Schematic drawing of the layout of ground lights for observation from space.

Key: 1. Direction of flight.

Test patterns on the ground were use to study certain visual functions of the cosmonauts. In the first stage of the studies, the ground tests were set up on the night side of the earth, something which precluded the influence of the powerful daytime background radiation of the earth's surface and the dense layers of the atmosphere. The studies were started during the flight of the "Voskhod" space vehicle in October of 1964. A special pattern of lights, consisting of three bands of lights, each of which included six point light sources and one powerful reference source which was used for reliable detection of the strips (Figures 2.3) was set up on the earth's surface far from populated areas and the interfering lights of cities. The lights in the strips were placed at an equal distance in each strip, where the spacing between the first and the second was 30 m, the second and the third was 60 m and thereafter 120, 240 and 500 m. The light power of the point sources was about $2 \cdot 10^5$ cd, where floodlights were used as the light sources, and sources of $5 - 10 \cdot 10^6$ cd, where aviation flare bombs were used. The first type of source produced an illumination at a distance of 400 km of about $4 \cdot 10^{-7}$ lux, i.e. such as stars of the 2^m magnitude, while the second type produced about $5 - 10 \cdot 10^6$ lux [sic, error in original], i.e. such as stars of magnitude -1 or -2^m.

Lights from flare bombs, which were ignited two minutes prior to the experiment were used in a study from the "Voskhod" space vehicle. The observations were made by cosmonaut V.M. Komarov through the forward porthole, inclined to the surface of the earth at an angle of 60 degrees. Prior to the start of the observations, V.M. Komarov dark adapted his vision for six to eight minutes. At a distance of about 400 km, all three strips of lights were detected and recognized from the configuration of their arrangement. V.M. Komarov observed the lights for one minute, and in this case the cosmonaut figured that he saw 12 lights separately in the final stage of the observations.

The investigations of V.M. Komarov from the "Voskhod" vehicle showed that the cosmonaut reliably detected and recognized strips of lights on the night side of the earth which had an apparent magnitude of about -1.5^m. The visual acuity was determined from the number of lights observed. It proved to be 0.5 - 0.7. The visual acuity of V.M. Komarov determined under ground conditions from a hatch marked test pattern was 1.4 - 1.5. A study of the visual acuity of V.M. Komarov using point sources of light generally fit well into the known relationship for the levels of visual acuity deter- from a lined test pattern and point sources.

Studies of the major visual functions during the mission of the "Soyuz-9" space vehicle were carried out to obtain correcting data as applied to the longer flight of A.G. Nikolayev. During this mission, about 200 separate test experiments were performed.

Taking into account the linear dimensions of the objects being observed and the orbital altitude of the space vehicle, the angular dimensions of these objects and the corresponding apparent visual acuity were computed (Table 2.1).

As can be seen from Table 2.1, it could also be assumed for these flights, based on objective data, that visual acuity in space apparently increases, but this applies almost exclusively to extended (linear) objects. The possibility of observing such objects will be treated in section 3.1.

The results of experimental studies make it possible to draw the conclusion that the change in the major visual functions under space flight conditions is comparatively small. These changes run from 5 to 40% for various visual functions and prove to be insufficient for the cosmonaut to notice them based on subjective impressions, arising in space. The conclusion can be drawn from this that the vision of cosmonauts in flight is just as reliable as on the ground. This permits the broad utilization of vision for the conduct of scientific research and the control of a space vehicle.

TABLE 2.1. Values of the Apparent Visual Acuity of the Crew Members of the "Vostok-3" and the "Soyuz-9" Space Vehicles

The Observed Objects	Angular Dimensions, angular minutes	Visual Acuity, units
The Volga River	no less than 10-20	less than 0.1
Major highway	0.15 - 0.40	1.5 - 4.0
Aircraft runways	0.5 - 1.0	1 - 2
Taxi-ways	0.15 - 0.40	1.5 - 4.0
Various ships	0.3 - 1.5	0.7 - 3.0
Wake behind a ship	1 - 3	0.3 - 1.0

2.5. The Dynamic Characteristics of a Cosmonaut's Activity During Visual Observations

The development of modern semiautomated space instruments for observation (sighting sextants, viewfinders, spectrographs, etc.) has specific features at the present time which are related to the conditions of space flight. If the activity of a cosmonaut in the execution of dynamic operations is analyzed, then one can come to the conclusion that this activity is basically the various dynamic responses of a person (the type of delays of an operator) to a stimulus, as well as the response of following or compensatory tracking. Proceeding from the indicated analysis, procedures for studying the dynamic characteristics of a cosmonaut's activity in space have been worked out, taking into account its various stages and duration [118].

The analysis of the data on the dynamic characteristics of operator activity performed on the basis of ascertaining the dependence between the frequency of an input signal and the quality of working with it, which were obtained during the flight of the "Soyuz-9" has generated particular interest. These materials are needed in the design of control systems for space vehicles, control units of sighting and astronavigational systems, etc. Practically identical data were obtained for these characteristics for both crew members of the "Soyuz-9". It is characteristic that the best tracking quality is observed at a frequency of about 0.2 Hz, i.e. approximately in the range which was noted in the work of the crew of the "Voskhod-2".

One of the most widespread kinds of motor activity of a cosmonaut-operator when recording the results of visual observations from a space vehicle is the guidance of a motion picture or still camera on a phenomenon of interest to the investigator and the subsequent taking of the picture. At the start of the flight, the effect of weightlessness and the increased emotional excitability serve as interference to a certain degree in the execution of this operation. Thus, for example, during the mission of the "Vostok-3", A.G. Nikolayev detected the wakes of seagoing ships not far from the coast of the African continent. The ships themselves were not seen - they were detected from the waves. The entire wake was reminiscent of a dashed line, where the dots were the ships, and the fading dashes were their wakes. Binoculars were focused through the porthole of the vehicle on the wakes of the ships. To precisely the image in the center of the ocular, the binoculars were shifted slightly, and in this case, the entire wave fell outside the field of view of the binoculars, i.e. too much force was used, where the force was intended for the weight of the arms and binoculars. During second and subsequent orbits of the flight, such phenomena were no longer noted. Sea piers were likewise viewed from space, however, it proved difficult to detect the ships moored to them visually. In all probability, this is related to the reduction in the contrast between the wall of the pier and the bodies of the ships, as well as to a certain reduction in the contrast sensitivity of the visual system. For this reason, the performance of special experimental studies to estimate the photo-aiming quality was included in the mission program of the "Soyuz-9". The work was performed with a camera, something which made it possible to determine the apportioned allowances for the change in the quality of the activity of a cosmonaut-operator when making aimed photographs and motion pictures in flight.

A.G. Nikolayev underwent the requisite special training prior to the flight in the "Soyuz-9", because of which, he performed aimed photography with a minimum error of 10 - 18'. Not only weightlessness, but also the unsupported positioning has the most significant impact of all on the reliability of the indicated operation. Thus, when working in weightlessness, but with the position of the body secured in a rest position, the mean error in the readings increases by a factor of almost 3.5, while when working in weightlessness in an unsupported position, this error increases by a factor of more than six.

It follows from the analysis made here that the recording of observed phenomena can be accomplished only in a secured position, for which it is necessary to equip the work positions with fastenings for the body of the cosmonaut at two to three points at the most probable locations for the performance of these operations (at portholes, viewfinders, sextants, etc.). In this case, the cosmonaut's arms should remain free to work with the equipment.

Thus, the analysis of laboratory data obtained during the preparation of the flight of the "Soyuz-9" vehicles, as well as results of the subjective accounts of the crew and special experiments included in the mission have demonstrated that the state of the visual communications channel of a cosmonaut and its dynamic characteristics undergo definite changes during a long mission. This is especially noted during the adaptational phase of the mission. Following the adaptation of the organism to flight conditions, the operational visual indicators and those of the motor analyzer approach the mean background levels. Considering the fact that the visual communications channel and the dynamic responses of a cosmonaut-operator are the psycho-physiological bases for visual observations, it can be assumed that a cosmonaut is a sufficiently reliable link in the semiautomatic and manual systems for visual observation.

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EFFECT OF DYNAMIC SPACEFLIGHT FACTORS ON THE ANIMAL BODY

Moscow VLIYANIYE DINAMICHESKIKH FAKTOROV KOSMICHESKOGO POLETA NA ORGANIZM ZHIVOTNYKH (Effect of Dynamic Spaceflight Factors on the Animal Body) in Russian 1979 signed to press 13 Mar 79 pp 4, 244-248

[Annotation and table of contents from the book edited by Doctor of Biological Sciences A. M. Genina, Izdatel'stvo "Nauka," 248 pages]

[Text] This book presents the results of physiological, biochemical and morphological investigations carried out using the "Cosmos-782" biosatellite. Rats aboard the biosatellite for a period of 19.5 days were investigated directly after the flight's end and also in the course of a 25-day period of readaptation to terrestrial conditions. A generalization of these data is of great importance for understanding the mechanism of the effect exerted on the organism by spaceflight factors, especially weightlessness. The book is of interest for specialists working in the field of space biology and medicine and also for a wide circle of researchers engaged in study of the effect of extremal factors. Tables 69, illustrations 109. Eight pages of bibliography.

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SPACE APPLICATIONS

UDC 502.3:629.78

THE STRUCTURE OF THE SPACE SYSTEM FOR STUDY OF THE NATURAL RESOURCES OF THE EARTH

Moscow ISSLEDOVANIYE ZEMLI IZ KOSMOSA in Russian No 2, 1980 pp 5-10 manuscript received 3 Sep 79

[Article by Yu.P. Kiyenko, The "Priroda" State Scientific Research and Production Center]

[Text] Since the first years of the existence of the Soviet state, our Party and government have attributed considerable significance to work on the study of the natural riches of the nation, their efficient utilization, preservation and reproduction, as well as the creation of new methods and means of nature study. Numerous Leninist decrees, USSR legislation, the five-year plans of the nation and the directive documents of the CPSU Central Committee and the USSR Council of Ministers are full of concern for the solution of this important problem.

The resolutions of the 24th and 25th CPSU Congresses oriented Soviet science and production towards the utilization of space equipment for the purposes of nature study. This new direction in the study of natural resources was established at the level of state scientific, engineering and economic policy and is being successfully realized through the joint efforts of Soviet scientists, designers, workers, cosmonauts and nature study researchers.

Experimental work in the field of remote sensing of the earth using space equipment has been underway in our nation, beginning with the first flights of man into space. They demonstrated the expediency of creating a special space system for the study of natural resources and the environment in the interests of numerous sectors of the national economy.

A detailed analysis was made at the outset of the needs of the national economy for orbital information, and based on this, the technical requirements placed on the ground and on-board equipment were determined, as well as the plan for work organization and the sequence for its performance, the procedure for the planning and coordination, and the system for transmitting information and utilizing it.

The studies showed that space information, as compared to aircraft data, has a number of advantages which follow primarily from the specific features of space platforms: the altitude and orbital speed of the flight.

These advantages consist in the following: in a reduction of the expenditures for making photographs; in the practically unlimited field of view (from local to global); in the high operational speed of data acquisition by virtue of the orbital velocity of the space vehicle; in the possibility of obtaining data on difficultly accessible regions, for example, the northeast of the nation, islands, the water areas of seas and oceans; in the generalization of the information, as a result of which the individual details disappear but the features of larger objects stand out; in the instantaneous registering of information on enormous territories; in the documental and objective nature of the information; in the possibility for the widescale utilization in information interpreting using the method of analogy and employing highly automated processing systems; in the improvement in labor productivity and reduction in expenditures for processing space data; in the possibility of formulating research on the basis of the principle from the general to the particular, while the traditional methods are based primarily on the systematization and generalization of numerous and labor intensive individual observations.

It has been determined that there are more than 1,200 scientific research, planning and production organizations, higher and intermediate special educational institutions which are interested in the use of the data on earth sensing from space. The optimum parameters of the state-wide space IPRZ system [system for the study of the natural resources of the earth] have been determined and the technical requirements placed on the periodicity and time of photographs, the number and characteristics of the spectral bands in which the sensing is to be conducted, the resolution of the terrain, the field of view, the kinds of information documents, etc., as a result of the generalization and ranking of their wishes.

An analysis of the trends in the technical realization of remote sensing of the earth has demonstrated the necessity for a constantly in service, multifunction, complex multiple link system with a high level of process automation for obtaining and processing information.

The design of the system entails the solution of a number of fundamental problems, the implementation of state-wide organizational measures and definite capital investments.

A systemic approach to the formation of the design concepts for the state-wide system of studying natural resources and the environment has made it possible to work out more economic and efficient approaches to its design, optimize its information capability, precision, operational timeliness and reliability under the condition of satisfying as completely as possible the needs of the national economy.

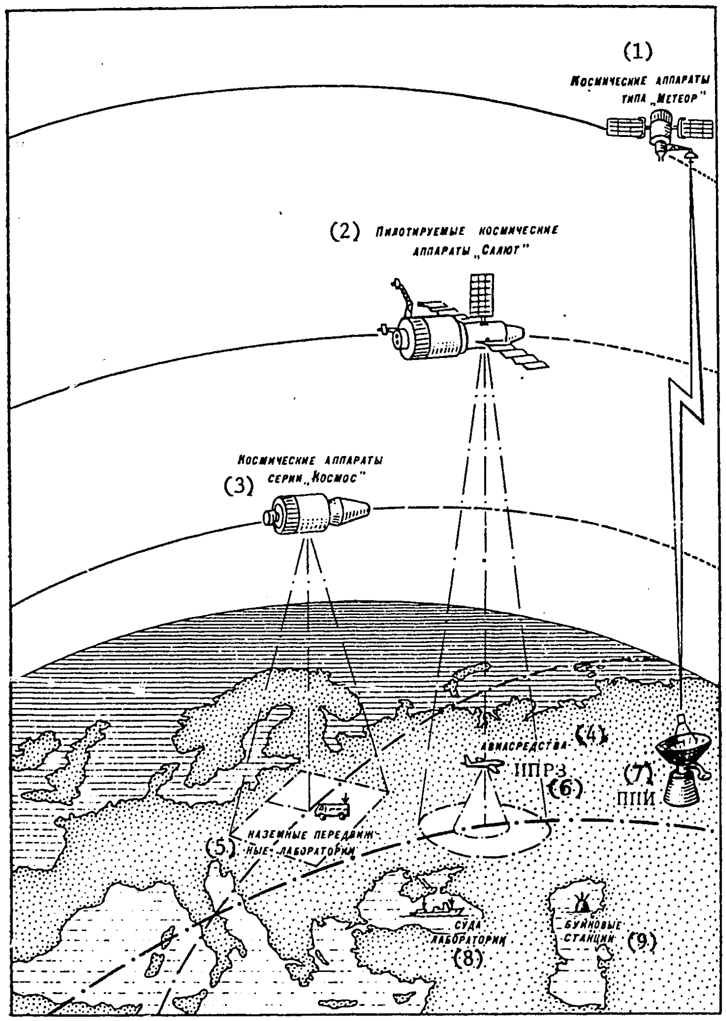
Considering the necessity for the development of two closely interrelated, and at the same time, rather independent approaches to obtaining and utilizing remote sensing data (of an operationally timely and long term nature), two specialized centers have been created in the nation: the State Scientific Research Center for the Study of Natural Resources (GOSNITs IPR) and the "Priroda" ["Nature"] State Scientific Research and Production Center. These centers have been assigned the tasks of the obtaining, intersectoral processing, storage and dissemination of space information for operationally timely and long term purposes respectively. The development of scientific procedural problems for earth study from space is being accomplished by the Institute of Space Research of the USSR Academy of Sciences in cooperation with a number of the nation's organizations and institutions. A network of primary, specialized and territorial organizations has been created and is being developed in the sectors of the national economy, which are performing the scientific research and production work on the goal oriented utilization of space information.

The state-wide space system for the study of natural resources and the environment can include both the permanently in service or on-demand following major components (see the Figure): manned space vehicles; the "Meteor" space vehicles; the "Kosmos" series space vehicles; aircraft laboratories; ground receivers and intersectoral information processors; a network of ground and sea test ranges, equipped with mobile and fixed equipment for contact and near-earth measurements; and a network of equipment and systems for targeted (sectoral) information processing.

We shall deal with the goal oriented function of the above-mentioned components.

Manned space vehicles, along with the performance of numerous other missions, are designed for the execution of a complex of experimental and trial production work on remote sensing of the earth, operating the on-board measurement and photographic equipment, performing visual and visual instrumented research. The first observations of the earth and the first photographs which provided nature study with assurance of the promising future for the use of space equipment were made from manned vehicles. The "Salyut" orbital space stations make it possible to install a complex of various instruments, including those having considerable size, weight and power consumption, as well as carry out specific sensing missions under comparable conditions using various receivers and create optimum conditions with human participation for the operation of the on-board equipment to obtain information on the earth.

Many experiments which were performed by cosmonauts in orbit have become the basis for establishing the technical requirements placed on new



The structure of the space system for the study of natural resources

Key:
1. "Meteor" space vehicles;
2. Manned "Salyut" space vehicles;
3. "Kosmos" series space vehicles;
4. Airborne facilities;
5. Mobile ground laboratories;
6. IPRZ [natural earth resource study];
7. PPI [satellite ground station];
8. Laboratory ships;
9. Buoy stations.

equipment, procedures for taking photographs and defining new areas of national economic utilization of space equipment.

In the future, orbital stations should play an ever increasing role in the study of natural resources and the environment both for obtaining long term information and for solving operationally timely problems, given conditions of outfitting with the requisite equipment, providing the necessary inclination of the orbit, and increasing the time period for the active existence and elevating the role played by cosmonauts.

The "Meteor" automated space vehicle carried out primarily hydrometeorological missions in the first stage of design and operation. These satellites provided for obtaining and transfering data via radio channels to ground receiving stations. On such satellites, besides the execution of the regular functions, a procedure was demonstrated and worked out for the operationally timely acquisition and utilization of space information serving the interests of a number of sectoral assignments to study the natural resources of the earth.

The "Meteor" satellites have been constantly refined, the quality and resolving power of the data have increased, and the sensing band has been extended, because of which the data obtained have come to find ever increasing application in nature study. This trend in the use of space equipment is one of the most effective in a technical economic sense for the study of rapidly occurring natural processes and the solution of problems requiring a large field of view with comparatively low resolution. The developmental trends of this approach of remote sensing promise a further growth in the resolving power of the obtained video information as well as the satisfaction of an ever increasing body of requirements of national economic sectors both in the area of operationally timely and long term assignments.

The "Kosmos" series satellites, which are used to study the natural resources of the earth, are equipped with various gear and are designed for returning photographic materials to earth by means of desent vehicles. The satellites of this type make it possible, for example, to take multiband photographs. The function of such satellites consists in the systematic support of the national economy with space photographic materials of a high spatial resolution for the solution of production and scientific problems of a long term nature in the interests of studying the earth's surface, its interior, the vegetative cover, seas and oceans, shelf waters, etc.

Aircraft laboratories are used in the system to carry out the research work related to the development of methods and technical means of remote sensing, the performance of ground experiments with satellites and obtaining information having an especially high resolving power. The equipment compliment and the nature of the flights is determined by the specific missions, and as a rule, changes frequently.

The most widespread type of aircraft laboratories is the AN-30. They have good navigation equipment, the requisite load capacity, flight range, practical flight ceiling and power supply.

A network of ground and sea test ranges is incorporated in the space system for studying natural resources. They take the form of sections of the ground surface, selected in characteristic physical and geographical regions of the country and which are sufficiently uniformly distributed for the entire territory. The test ranges are supported with scientific and technical documentation, which a provides a description of and the requisite parameters for the natural formations found in them and makes it possible to evaluate the information content of remote sensing materials which are obtained in an operationally timely manner and without excess expenditures. Satellite observation and measurements, comprehensive interdepartmental research on the development of sensing equipment and methods of interpreting space information, etc. are carried out on the test ranges.

Satellite ground observations are made using mobile and fixed complexes and units for contact and near earth measurements. They make it possible to determine the parameters of the atmosphere, the spectral reflectivity of natural formations, the resolving power of remote sensing data, the working out of the technical requirements placed on future equipment, methods of interpretation, etc.

Remote sensing information which is received from space, from aircraft laboratories and as a result of ground measurements is forwarded to the state-wide intersectoral centers, and after appropriate processing, is routed to the sectoral users for utilization in the study of natural resources and the environment.

Remote sensing data on the earth, obtained from the existing space equipment, has found wide applications in the solution of many scientific problems and production tasks, and has become the object of international cooperation.

Work on the utilization of space photographs in geological studies of extensive regions of the nation has been incorporated in the state plans; mapping difficultly accessible regions and updating topographical maps, studying the timber reserves, developing plans for large engineering structures, including hydroelectric stations, oil and gas pipelines, major canals; taking a comprehensive inventory of natural resources, etc. The economic impact of the utilization of space information today already amounts to several tens of millions of rubles. To meet future needs, the IPRZ space system should be expanded and refined. Automated space vehicles which transmit data via radio channels and return photographic materials to earth, as well as multifunction manned orbital stations will remain the major links in the system in the future also. In this case, the information capacity of the sensing should increase, as well as the operational timeliness and global nature of the view of the earth's surface. An important task is the mastery of the highest information capacity infrared and microwave bands of the electromagnetic spectrum, the use of active radars and providing for an all-weather capability in data gathering.

The development of means for ground processing of photographs of the earth from space has become an urgent need. In essence, it is necessary to create a diversified automated industry for the transformation and goal oriented interpretation of space data based on high speed optronic and computer systems. Based on expert evaluation, the expenditures for the development of the IPRZ space system have already been paid back at the present time, and in the immediate future, the savings will be no less than 12 to 17 times greater than the outlays and will substantially increase in the future. These figures are evidence in favor of universally accelerating the work to bring nature study from space into being.

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THE "METEOR" SPACE SYSTEM IN THE HYDROMETEOROLOGICAL SERVICE

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[Text] The "Meteor" system which is intended for obtaining information on the natural environment in the interests of hydrometeorology consists of both operational and experimental satellites. The operational satellites are an integral part of the overall system for hydrometeorological observations. Their mission includes the regular obtaining of observa tional data for the forecasting organs of the USSR Goskomgidromet [State Committee on Hydrometeorology], which satisfy the needs of various sectors of the national economy for hydrometeorological information and forecasts. The experimental satellites are used to perform scientific research and experimental design work, directed towards expanding the make-up of hydrometeorological observations and improving methods for obtaining them. The operational satellites are equipped with a complex of equipment of the same type and are placed in quasipolar orbits at an altitude of 900 km and an inclination of 81° to the plane of the equator, and since the equipment compliment of the experimental satellites is not of the same standardized type, they are launched into quasipolar synchronous solar orbits at an altitute of 600 km. At the present time, refined second generation "Meteor-2" satellites are being used to obtain operational information in the "Meteor" system, which in terms of their design specifications are superior to the first generation satellites [1, 2].

The functioning of the operational satellites according to plan over the last 13 years has made it possible to acquire experience with the practical utilization of satellite observation data in the interests of hydrometeorology, as well as to work out and refine methods for processing and interpreting data, and train specialist personnel in the field of satellite hydrometeorology.

The operationally timely information on the status of the atmosphere, cloud cover, dry land and ocean surfaces, which is extracted from the data of satellite observations, has substantially supplemented the set of hydrometeorological observations made by traditional methods. It has made a considerable contribution to improving the analysis and forecasting of weather formation processes above the oceans and the difficultly accessible dry land regions which occupy overall four-fifths of the surface of our planet. However, in regions with a sense network of ground meteorological stations, satellite data has made it possible to make corrections in the analyses of weather maps.

Considerable successes have also been achieved in the field of interpretation of satellite photographs in the visible and infrared bands of the spectrum. These results have especially enriched traditional hydrometeorological observations. Besides the analysis and forecasting of the weather, satellite photographs have found applications in hydrology, oceanology, climatology and other fields of hydrometeorology. They were an important source of information for flight services, navigation and fishing, agriculture, forestry and water management as well as other sectors of the national economy.

The direct transmission of images in the visible portion of the spectrum in real time were an extremely effective tool of the "Meteor-2" satellites. This has made it possible for all of the interested forecasting organs, including those of other nations, to obtain photographs for the region of their own activity directly from the satellites during their flyby by means of comparatively simple equipment.

The research which has been carried out over recent years by means of experimental satellites has demonstrated the theoretical possibility of increasing the volume and composition of satellite observation data in the interests of hydrometeorology [3]. Although individual experiments have not been so successful that the data obtained could be used on a regular basis, they have nonetheless made it possible to plan ways of improving the quality of new satellite data so as to satisfy the requirements placed on the observations.

To more precisely specify the role of the "Meteor" space system in hydrometeorology, we shall consider the possibilities of utilizing the operational observational data obtained using it, as well as the results of scientific experiments performed with the system satellites.

The utilization of the operational information. The composition and basic characteristics of the hydrometeorological equipment of the "Meteor-2" operational satellites, as well as well as the forms of observational data representation following processing are shown in Table 1. An eight channel

TABLE I The Equipment of the "Meteor-2" Operational Satellites and the Forms of Observational Material Representation

The Equipment and Its Characteristics	The Observational Materials (the Output Product)
A scanning telephotometer for direct transmission of images in the visible portion of the spectrum (0.5--0.7 μm). The width of the field of view is 2,100 km with a resolution of 2 km at the nadir	Individual photographs and photomosaics made from the photographs of 2 to 3 orbits for the region of the receiving station in a radius of up to 2,200 km (2 to 3 times per 24 hours)
A television type scanner with the capability of storing images in the visible portion of the spectrum (0.5--07 μm). The width of the field of view is 2,200 km and the resolution is 1 km at the nadir	Individual photographs and photomosaics from photographs for various regions of the globe (2 to 3 times per 24 hours), photomosaics for the artic and antartic seas from photographs of the ice cover when there is little cover (once every 5 days).
An infrared scanning radiometer (8-12 μm) with an image storage capability. The width of the field of view is 2,600 km and the resolution is 8 km at the nadir.	Global photomosaics separately for the northern and southern hemispheres and the tropical zone; individual photographs and maps of the radiation temperature of the earth's surface and the altitude of the upper boundary of the clouds for various regions of the globe (2 times every 24 hours); the coordinates of tropical cyclones and data on the quantity of clouds at the nodes of a regular grid for the entire globe (2 times every 24 hours using images in the visible portion of the spectrum).
An eight channel scanning infrared radiometer for 11.10, 13.33, 13.70, 14.24, 14.43, 14.75, 15.02 and 18.70 μm. The width of the field of view is 1,000 km and the angular resolution is 2°.	Global data from thermal sensing of the atmosphere.

scanning infrared radiometer for thermal sensing of the atmosphere has still not been incorporated in the complement of the transducers which provide for the operational observation.

The greatest successes in the field of the operational utilization of satellite data were achieved in the compilation of synoptic weather forecasts. In contrast to discrete ground observation, these data, in the form of radiation temperature fields and images, represented a more complete picture of the distribution of cloud cover over the earth's surface, something which is extremely important in and of itself for the evaluation of the actual state of the weather. They simultaneously make it possible in different regions of the globe to study in more detail the relationships between cloud cover structure and weather generating processes, which result in the variability, evolution and movement of cloud cover. Based on the relationships which were ascertained from satellite data, cloud cover was successfully used to a greater extent as an indicator of weather shaping processes, something which improved the procedure for predicting them.

It was above all possible when forecasting by the synoptic method to improve the analysis of large scale atmospheric processes, especially in regions which were inadequately covered by conventional observation. Photographs in the infrared band of the spectrum, obtained on the day and night sides of the earth, proved to be more suitable for these purposes. In contrast to photographs in the visible spectrum on the day side of the earth, they contain a greater generalization of the fin details of the image, something which eliminates the interfering influence of the latter when interpreting large scale cloud formations. Moreover, photographs in the infrared band are a better representation of the vertical field structure of the cloud cover, emphasizing the vertically most developed large scale cloud systems in the image with high brightness. In photographs in the visible low clouds and fog simultaneously have a comparatively high image brightness, something which with a lesser degree of generalization of the images in a number of cases masks the specific structural features of large scale cloud systems developed vertically.

Satellite data have also been used successfully to improve the analysis of synoptic scale and mesoscale atmospheric processes and phenomena. Photographs in the visible range have proved to be most suitable for these purposes, where these photographs permit the detection and tracing of the development of numerous details of cloud cover. Along with this, the combined analysis of images in the visible and infrared bands has made it possible to specify more precisely and supplement the results obtained from the analysis of only one kind of image. For this reason, the joint utilization of satellite photographs in the visible and infrared bands of the spectrum has become traditional in synoptic analysis.

The location and intensity of cyclones inside and outside the tropics, the location and activity of atmospheric fronts and zones of a convergence within the tropics, the location of areas of precipitation, the foci of active thunderstorm activity, high cyclones, troughs of low pressure and high pressure ridges as well as jet streams are successfully determined from the nature of a cloud cover image. The stability of air masses has been successfully evaluated also; the influence of terrain orography, the thermal inhomogeneity of the subjacent surface and local circulation on cloud cover distribution has been traced, the nature of the field of air currents has been assessed, etc.

Studies of the dynamics of cloud fields have made it possible to develop recommendations directly on the basis of photographic images for the prediction of the occurrence, evolution and movement of cyclones, atmospheric fronts and other meteorological objects, which are weather vehicles. The recommendations are based on the fact that the photographic image has its own individual features at each stage of the development of these objects, something which also makes it possible to determine the probable trend of their evolution and movement based on the structure of the cloud field.

The method for the analysis of mesoscale cloud forms which was worked out on the basis of satellite images, has made it possible to identify the physical conditions for their formation against the background of large-scale atmospheric motions. Considerable attention has been devoted to the study of the mechanism of mesoscale circulation, related to convection processes. This research was stimulated by the partial appearance in photographs of convective cloud cells of different types and convective cloud banks, the mechanism for the formation of which was insufficiently clear. For the purpose of ascertaining the physical factors determining the shape of the ordered convection in the atmosphere, a large series of experiments was undertaken to numerically model the convective motions for various conditions of a large scale flow, with a subsequent check of the theoretical conclusions against factual data [4-6]. The results of the studies performed on the mechanism of mesoscale convective motions have made it possible to more completely interpret the satellite images of cloud cover.

Satellite data on the radiation temperature have found applications in the practical work of analyzing and predicting weather for the approximate estimation of the temperature of the subjacent surface the altitute of the upper boundary of the clouds. An operational scheme has been developed for determining the altitude of the upper boundary of clouds as applied to regions with an insufficient volume of conventional observation.

All of these possibilities for the interpretation of satellite data in the form of radiation temperature images and fields have made them an important component in the synoptic compilation of general service weather forecasts and emergency warnings of dangerous and especially dangerous weather phenomena. Their utilization has made it possible at the same time to improve the meeting of the specialized requirements of various sectors of the national economy for operationally timely hydrometeorological information and forecasts.

Satellite data contained information useful for aviation, in particular, for preflight briefings of crews and the compilation of aviation forecast maps (bulletins) of dangerous weather phenomena, especially on routes running over oceans, mountains, deserts and polar regions [7].

In the resolution of fishing and shipping problems, satellite observations over oceans are frequently the only source of information on the position and intensity of typhoons and cyclones which have developed, as well as active atmospheric fronts and regions of thick fog, which have a substantial impact on sea activity. These observations make it possible to not only improve weather forecasts for sea navigation, but also to gain certain information on the state of the sea surface. Thus, an indirect judgement can be made from the structure of the cloud cover in photographs in the visible portion of the spectrum both concerning the maximum wind velocity and the strength of storm wave agitation of the sea surface when developed typhoons and cyclones, which have attained a high intensity, pass through.

An extremely effective tool for the evaluation of the ice situation on frozen seas are photographs in the visible spectrum. A procedure developed for interpreting them has made it possible to compile maps of the distribution of drifting ice with respect to coverage density, structural details and precision, which are not inferior to ice reconnaissance maps [8]. This information, which can be extracted from satellite data, is extrememly important for the activity of seagoing vessels of the transportation and fishing fleets.

Photographs in the visible band of the spectrum contain useful information for meeting the specialized requirements placed on agrometeorological services for agriculture. Their utilization in conjunction with the data from conventional observations makes it possible to more precisely determine the boundaries of snow cover and areas having inadequate, adequate or excess snow reserves for wintering over and supporting agricultural crops in good condition, as well as better follow the appearance and disappearance of the snow cover. In estimating the dynamics of the development of atmospheric processes, the utilization of the entire volume of satellite data aids in more reliably determining the trend of a change in agrometeorological conditions which are important to agricultural production. They play a defi- part, especially in forecasting frosts, making it possible to consider more complete and precise data on cloud and snow cover.

Photographs made in the visible portion of the spectrum contain extremely valuable information for forest management. Based on an analysis of them, the dynamics of the development of foci of large forest fires have been successfully detected and followed, where these are rather clearly identified from the light gray image of the smoke trails, which extend out from the foci of the fire in the direction of the prevailing wind; cloud cover promising for artificially producing precipitation on forest fires has also been ascertained. In conjunction with ground observations, satellite data simultaneously improve the assessment of the possibility for the occurrence of fire hazard situations. All of this makes it possible to optimize efforts to combat forest fires, by maneuvering the appropriate personnel and equipment in an operationally timely manner.

In the interests of hydrology, photographs in the visible portion of the spectrum permit the analysis of ice phenomena on large rivers and lakes, as well as a snow cover in the basins of large rivers. The icing up and dynamics of freeing large rivers and water reservoirs from ice, the position of the edges of the ice cover and continuity over large lakes and water reservoirs have been traced successfully in the analysis of ice phenomena [9]. This information aids in providing timely warnings to the river fleet on the opening and freezing of rivers, as well as providing correct information for the fleet on the ice status and time periods for the start of navigation.. It is possible in the analysis of the snow cover to estimate its area and distribution over the water catchment basin of rivers. A snow cover of down to 5 - 10 cm can be ascertained for the snow depth. The resulting data on snow cover, although it does not contain all of the characteristics of its condition, play an important part in estimating the contribution of the snow cover to the formation of the snow melt drainage of rivers during the spring flooding.

The accumulation of satellite observation materials has stimulated the development and utilization of the methods of hydrometeorological forecasts of varying timeliness. As was indicated above, significant results have now been achieved in the field of short term forecasts, however, the studies which are being made inspire the hope of obtaining positive results in the field of long range forecasts also. Research has been started on the development of new schemes in the field of long range forecasts, which take into account more complete satellite data on cloud cover, which is one of the major regulators of the interaction between the circulation and radiation processes in the atmosphere, which determine the variations in the weather. These investigations have not as yet been completed, but preliminary results are promising [10, 11].

The results of experiments. The possibilities of remote observation methods in various regions of the visible, infrared and microwave spectra were studied within the framework of the program realized using the "Meteor" experimental satellites. Experiments to work out methods for obtaining new kinds of satellite data were based on the comprehensive analysis of data of satellites, aircraft and ground observations. The composition of the experimental hardware, installed in the satellites, its characteristics and functions are shown in Table 2.

TABLE 2. The Experimental Equipment Installed in the "Meteor" Satellites

The Equipment and Its Characteristics	Function
An infrared spectrometer with a range of 10 - 17 μm and an angular resolution of 6 x 1.5°	The determination of vertical temperature profiles in the atmosphere
A spectrometer--interferometer (German Democratic Republic) with a range of 6.25--25 μm and an angular resolution of 2°	The determination of vertical temperature profiles and water vapor and ozone content in the atmosphere
A radiothermal polarization detection and ranging unit for a wavelength of 0.8 cm with two orthogonal polarizations having an angular resolution of 2.5°	Tracing regions of precipitation, determining the water reserves and phase composition of clouds
A three channel microwave radiometer for wavelengths of 0.8 cm (scanning in a 1,000 km strip), 1.35 and 8.5 cm (at an orbital altitude of 900 km) with terrain resolutions of 24 x 30, 90 x 90 and 100 x 100 km respectively	The determination of the overall moisture content of the atmosphere, water content of clouds, temperature of the sea surface and tracing zones of precipitation and ice cover boundaries
A scanning infrared polarimeter with bands of 1.5--1.9 μm and 2.1--2.5 μm, a width of the field of view of 2,200 km (at an orbital altitude of 900 km) and an angular resolution of 3°	The determination of the phase composition of clouds
Equipment for studying the solar--atmosphere linkage mechanism, including: --A four channel corpuscular spectrometer with a range of 0.3--30 KeV; --A scanning infrared radiometer for oblique sounding (0.3--30 μm)	Obtaining data on the intensity of corpuscular radiation acting on the upper atmosphere, and the intensity of thermal infrared radiation of the upper atmosphere which is one of the agents for energy transfer from the upper to the lower atmosphere.
A four-channel television type scanner (0.5--0.5, 0.6--0.7, 0.7--0.8 and 0.8--1.1 μm) with a width of the field of view of 1,930 km for the terrain and a resolution of 1,000 x 1,700 m at the nadir	Obtaining combined images of the ground surface and cloud cover in various bands of the visible and near infrared spectrum
A two-channel television type scanner (0.5--0.7 and 0.7--1.1 μm) with a width of the field of view of 1,380 km for the terrain and a resolution of 240 m at the nadir.	[Same as above]

Figure 1. Fragment of a photograph of the Yenisey River basin in the 0.7 - 1.1 μm band with an image of the high water ("Meteor", medium resolution, 5 June, 1978).

Key: 1. Yenisey River;
2. Lower Tunguská River.

The results of an experiment with thermal sensing of the atmosphere by means of an infrared spectrometric apparatus in the 10 -- 17 μm band, including the CO_2 absorption band, confirmed the theoretical possibility of reproducing the temperature profile in the atmosphere based on the spectrometric variations [12]. The temperature fields reproduced from satellite and radio sounding measurements were in agreement. The processing of the mass of measurements, however, indicated inadequate precision in the determination of the temperature. To reduce the errors, it was necessary to increase both the precision in the spectral radiation measurement and (primarily) the accuracy of the data on the characteristics of the atmospheric absorption. It was likewise necessary to overcome difficulties related to taking the cloud cover intruding in the field of view of the instrument into account.

The possibilities of improving the precision of remote sensing of the atmosphere were studied by means of a spectrometer--interferometer, developed in the German Democratic Republic, based on more precise measurements of quasicontinuous spectra in the 6.25 - 25 μm band [13]. Besides determinate methods of solving inverse problems, attempts were made in this case to apply statistical methods, the basis of which is the joint utilization of measurements of spectra from satellites and sounding data from the earth. The utilization of measurements of quansicontinuous spectra made it possible to increase the precision of the reproduction of the vertical temperature profiles, especially, close to the tropopause, and of the determination of the total water vapor and ozone content in the atmosphere. The comparatively high precision of the measurements made it possible to likewise check the possibility of estimating the impact of cloud cover and the consideration of it in solving inverse problems.

A large volume of measurements was obtained in the microwave band by means of radiothermal polarization detection and ranging equipment at a wavelength of 0.8 cm with two orthogonal polarizations (horizontal and vertical) [14]. An analysis of the data from these measurements made it possible to identify regions of precipitation, quantitatively estimate the water reserves of clouds and the intensity of precipitation (three gradations) and determine the phase composition of clouds. The reliability of these estimates is increased in the case of the combined analysis of satellite polarization data and the simultaneously obtained images of cloud cover in the infrared band (8--12 μm). The determination of the phase composition of clouds also proved to be possible based on measurements of the polarization characteristics of reflected solar radiation in the near infrared region of the spectrum (1.5--1.9 and 2.1--2.5 μm) using a scanning polarimeter. Crystalline and droplet clouds were differentiated by this method with a probability of 86% [15].

A limited volume of measurements, especially at a wavelength of 8.5 cm, were obtained using a three channel radiometer at wavelengths of 0.8, 1.35 and 8.5 cm. It was possible from an analysis of these measurements to determine the overall water vapor content in the atmpsphere and that of liquid-drop water in clouds, as well as to ascertain the regions of strong and moderate precipitation, trace the boundaries of ice and estimate its coverage density [16].

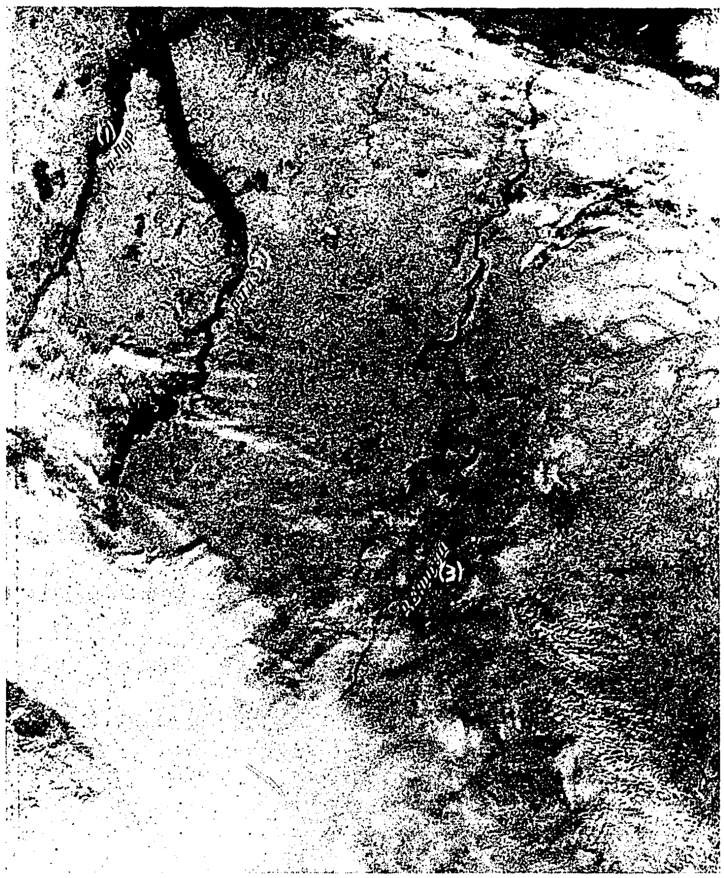

Figure 2. Fragment of a photograph of the Yenisey River basin in the 0.7 - 1.1 μm band after the passage of the high water ("Meteor", medium resolution, 30 June, 1978).

Key: 1. Pur River;
2. Taz River;
3. Yenisey River.

One of the important areas of the research program being carried out with the "Meteor" experimental satellites is the analysis of the capabilities of a multiband photographic method in the visible and near infrared bands of the spectrum using a television type scanner. The problem posed in the choice of the equipment parameters was that of taking multiband photographs of the ground surface with differing degrees of image generalization, but having a relatively large field of view, so as to have the capability of studying the status of large natural objects and tracing the short term and seasonal phenomena involving large territories. Photographs with a very high resolution are little suited to these purposes because of the narrowness of the field of view and the long period for a repeat flyby over the same region. Photography using a four-band unit was carried out in a strip 1,930 km wide with a resolution of 1,000 x 1,700 m at the nadir, and using a two-band unit - in a strip 1,380 km wide with a resolution of 240 m at the nadir. In the first case, the photographs were called low resolution ones, and in the second, medium resolution photos.

An analysis of the multiband photographs which were obtained demonstrated that, as compared to single band photographs, they have a greater information capacity, especially for the study of the state of ground surface objects, something which is related to the capability of using the dependence of the reflectivity of natural objects on wavelength when interpreting the photographs.

The increased viewing coverage, with the selected level of generalization of fine details, has made it possible to reliably recognize several large natural objects simultaneously and estimate their status from multiband photographs, and when using sequential photographs, the dynamics of the development of various processes and phenomena can be followed over large territories. Physical-geographical regions and specific landscape features of a terrain have been successfully distinguished, singling out deciduous and coniferous forests, steppe, forest-steppe, desert, semi-arid and tundra regions, boggy, forested and lake covered territories and territories with differing vegetation states. The flood plains of rivers which flood and the retained increased moisture and elevated thickness of the vegetation have been distinguished, as well as the dry beds of dried out and temporary water courses, pollutant effluents near the mouths of rivers, sand and dust storms, irrigated land and water reservoirs, sandbanks, underwater vegetation in shallow waters, surface currents in individual regions, pollution of surface waters near port cities and snow close to industrial centers, etc. Such elements of the landscape as the mesorelief, the drainage system and the soil and vegetative cover are the most clearly reflected in the photographs of plains territory. In low and moderately mountainous regions, large features of the relief and the erosion partitioning of the territory stand out first of all, as well as the change in soil and vegetative zones. In high mountains, the relief of ranges, valleys between mountains, large valleys which emphasize breaks in the earth's core, outcroppings of rock as well as snow cover and icebergs are the most clearly pronounced. The specific features of the morphology of macroscale and mesoscale sand areas stand out in sandy deserts. Short term and seasonal changes in the landscape of a terrain due to the appearance and disappearance of snow cover the thawing of surface layers of permafrost soil, the occurrence and propagation of sand and dust storms, the spreading of forest fires, the blowing away of snow cover, the spreading and fading of vegetation, including the influence of precipitation on its condition, the

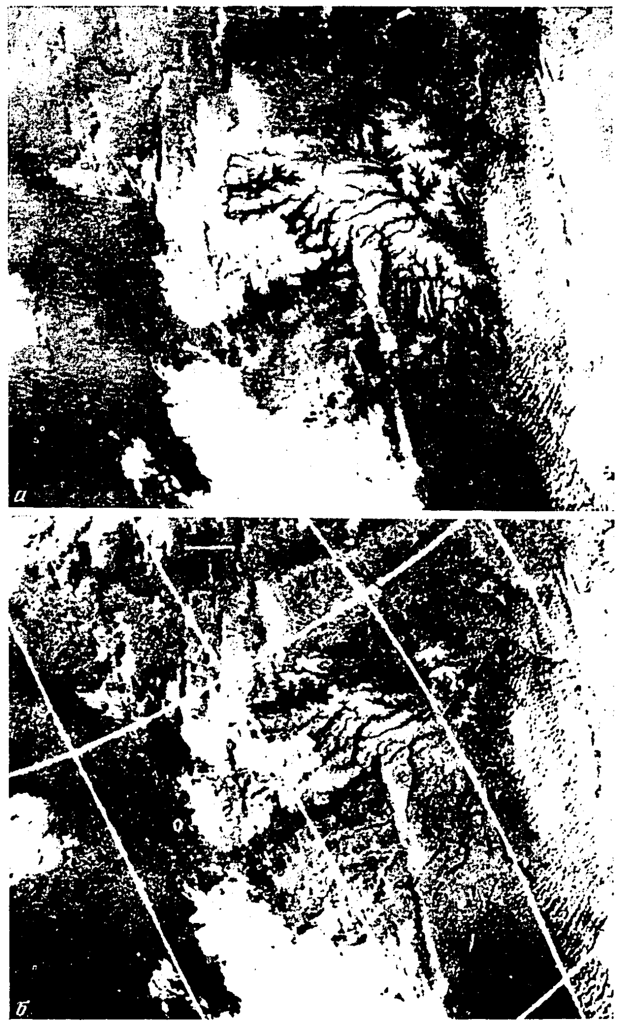

Figure 3. Fragments of images of the Putorana mountains in the 0.6 - 0.7 μm (a) and 0.8 - 1.1 μm (b) bands during the thawing of the snow ("Meteor", low resolution, 27 July, 1976).

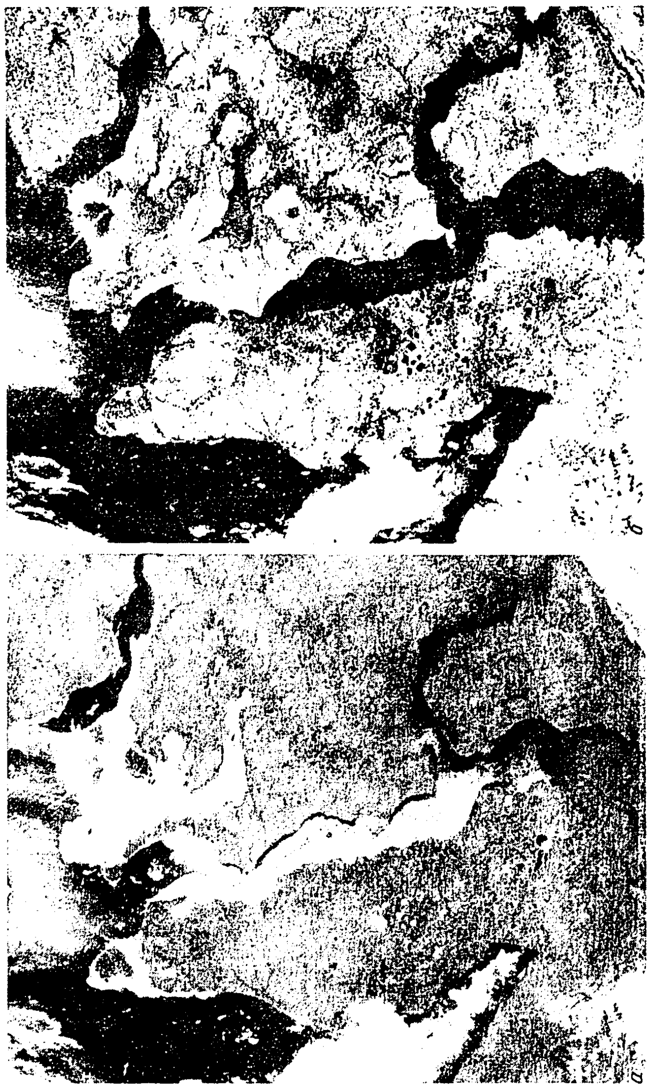

Figure 4. Fragments of images of the Gulf of the Ob R.ver in the 0.6 - 0.7 μm (a) and 0.8 - 1.1 μm (b) bands in the case where water from melting snow appears on the surface of the ice ("Meteor", low resolution, 8 July, 1976).

onset of dry periods, the maturing and harvesting of agricultural crops, etc., are all followed simultaneously in various physical-geographical regions.

The possibility of the interpretation of multiband photographs which have been delineated here make them a material for multisectoral utilization. The interpretation results assist in specifying the various kinds of topical maps more precisely: general geographical, topographical, geological, geobotanical, hydrological, agricultural, forest lands and other small and intermediate scale maps which are important to the study of the natural environment and natural resources.

The hydrometeorological information on processes and phenomena at dry land and ocean surfaces, obtained by means of multiband photographs, is distinguished by the considerable completeness, detail and precision as compared to that which is extracted from the analysis of single band photographs in the visible portion of the spectrum from the "Meteor" operational satellites. The considerable completeness and better quality of the information is achieved through the higher resolution of multiband images and the capability of using band distinctions in their interpretation, as was indicated above, where these distinctions are related to the change in the reflectivity of natural objects as a function of wavelength.

The boundaries and coverage density of ice on rivers, lakes and water reservoirs are estimated more precisely in the case of hydrological interpretation, ice gangs and icing up are traced in more detail, as are the dynamics of ice thawing and the flooding of river flood plains during floods and overflows of rives, especially in medium resolution photographs which make it possible to estimate the flooding area. The fragments of medium resolution photographs in the 0.7 - 1.1 μm band shown in Figures 1 and 2 illustrate the possibilities for tracing the floods of rivers during the spring high water. Along with this, multiband photographs contain more complete and precise information, which is needed for hydrological forecasts of the outflow of plains and mountain rivers, and calculations of the intensity of floods and high water [17, 18]. In particular, better information is provided on the basis of their analysis on the boundaries of the spread and the distribution area of snow cover and the catchment basins of rivers. The areas and boundaries of the simultaneous snow thaw and its duration have likewise been specified more precisely, and the degree of forest cover of the catchment basins has been determined more precisely. During the winter period, the extent of forest cover is rather easily determined with an accuracy of 10 to 15 percent for forest areas consisting of coniferous and deciduous species [17]. Some of the possibilities for tracing the melting of snow and ice in low resolution photographs are shown in Figures 3 and 4. Because of the clear image of the drainage, multiband photographs can also be used to specify the overall area of the water catchment basis of rivers more precisely, as well as the depth and length of small rivers and the gully and ravine systems for the purpose of estimating the hillside runoff into large rivers.

Figure 5. Fragment of an image of turbid waters running out into the Black Sea, in the 0.5 - 0.7 μm band ("Meteor", medium resolution, 7 May, 1978).

Key:
1. Black Sea;
2. Sukhumi;
3. Caucasus Range;
4. Ingura River;
5. Batumi.

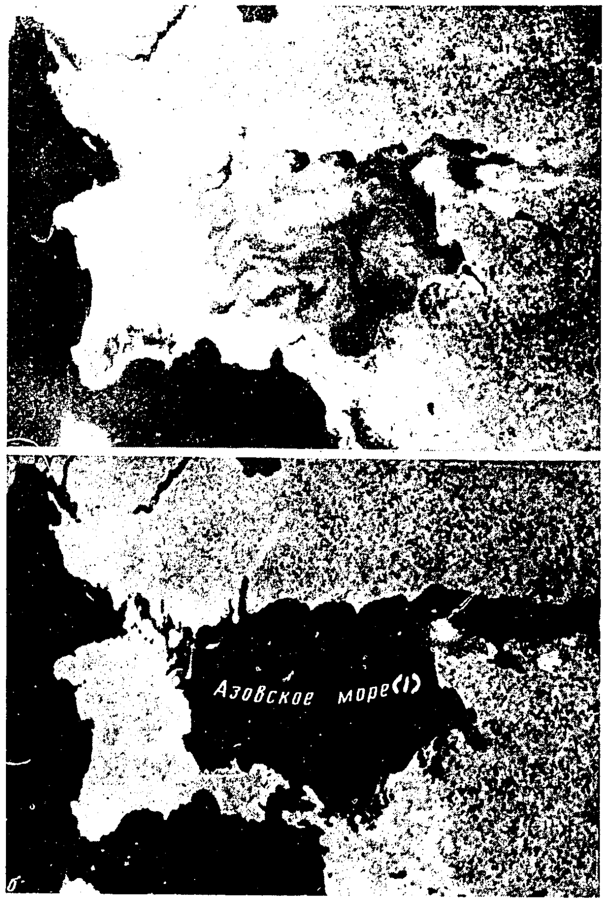

Figure 6. Fragments of images of the water surface of the Sea of Azov in the 0.6 - 0.7 μm (a) and 0.8 - 1.1 μm (b) bands during the florescence of phytoplankton ("Meteor", low resolution, 4 September, 1977).

Key: 1. Sea of Azov

APPROVED FOR RELEASE: 2007/02/08: CIA-RDP82-00850R000200100044-0

Figure 7. Fragment of an image of a region of intensive agriculture in the 0.7 - 1.1 μm band ("Meteor", medium resolution, 27 April, 1979).

River effluents of turbid waters (Figure 5) into seas and lakes, as well as fouling created in shallow waters as a result of storm waves on the water surface are most easily identified when interpreting water surface images [19]. Differences in the band i .ges aid in the analysis of inhomogeneities of the stream of effluents according to the content of suspended substances as well as in the more precise specification of the boundaries of the inhomogeneities and tracing their propagation. The florescence of

Figure 8. Fragment of an image of the foci of fires and burned out areas of vegetation in Western Siberia in the 0.5 - 0.7 μm band ("Meteor", medium resolution, 5 August, 1977).

Key:
1. Nyda River;
2. Pur River;
3. Taz River;
4. Chasel'ka River;
5. Pyakupur River.

phytoplankton in internal water basins is identified (Figure 6) as well as in coastal seas; and in some regions, pile-up and dissipation phenomena and circulation of surface waters are traced. When interpreting an ice cover in seas and oceans, besides the more accurate determination of the boundaries, density and drift, it is possible study certain other morphological features of its structure. For example, the eddy formation in the fracturing ice cover has been traced successfully, which is related to the intermixing of the water masses when the ice thaws and the velocity shift of sea currents, the deformation of the solid ice fields under the influence of sea currents, etc. The information content of ice images increases markedly with an improvement in their resolution, and the band distinctions of the images basically aid in following the appearance of water on the ice surface and its contamination.

When solving agrometeorological problems, multiband photographs, especially medium resolution ones can be effectively utilized in conjunction with ground data to more precisely determine the area of snow reserves when evaluating the conditions for wintering over and providing moisture for agricultural crops, as well as for tracing the appearance and decline of the snow cover. Along with this, in regions saturated with agricultural lands, they can aid in assessing the seasonal development of agricultural crops and the impact of drought conditions on their condition, and in semiarid regions, in the determination of the reserves of pasture vegetation over large areas. In some cases, a judgement can be made concerning the course of agricultural work [20]. Because of the generalization of fine detail, individual agricultural fields, generally speaking, are not distinguished on low resolution photographs, but with sufficient saturation of the territory with agricultural land, they impart a definite pattern to its image, which depends on the state and distribution of the vegetation at the moment the picture was taken. One of the interpretation criteria for the influence of drought conditions on the status of agricultural crops is, in particular, the increase in image contrast of flood plain areas of agricultural lands. Regions saturated with agricultural lands are more clearly identified on medium resolution photographs, where under favorable photographic conditions, large fields can be seen (Figure 7).

The possibilities of identifying the foci of fires in multiband photographs are being improved [21]. Band distinctions in the smoke trails make it possible to draw a conclusion concerning the presence of certain combustion products in them. The intensity of fire foci and the area of burned out sections of vegetation can be estimated more precisely from medium resolution images (Figure 8).

The research experience acquired at the present time in the utilization of satellites shows that by using them a large volume of hydrometeorological and geophysical parameters can be obtained, which are necessary for the refinement of weather forecasts, the solution of problems in hydrology, oceanology, monitoring the pollution of the natural environment, studying the climate, etc. [22]. To obtain more complete and high quality information by remote methods, the formulation and performance of comprehensive studies of the atmosphere, cloud cover, ocean surface and dry land surface as an integral system are needed. This system should be treated as a single one, not only from the viewpoint of weather and climate formation, but also viewed from a comprehensive approach to the problems of determining the parameters of its condition. This is due to the fact that remote methods of obtaining information are based on the analysis of the characteristics of electromagnetic radiation, which in the general case depend on an entire set of factors, where this dependence is frequently quite complex, something which places limitations on the completeness and quality of the information. Thus, for example, when determining the parameters of the state of the earth's surface, it is necessary to take into account the influence of the atmospheric radiation on it, and when determining the parameters of the atmosphere, one must consider the influence of the ground surface radiation. This complex dependence of the radiation measured from satellites also dictates the necessity of a comprehensive approach to the determination of hydrometeorological and geophysical parameters, consisting in the synchronous measurements of the emitted radiation radiation in the most diverse bands of the spectrum and the formulation of remote sensing tasks based on the determination of a set of parameters. Working from modern concepts, the realization of multispectrum measurements simultaneously in the visible, infrared and microwave bands of the spectrum is the primary way of increasing the role of satellites in the overall system of hydrometeorological observations. The diversity of the tasks and methods of utilizing space information in this case requires the installation of equipment in satellites which differs not only in the number of spectral bands in the various spectrum ranges, but also in the resolution, amount of terrain covered and the operational timeliness in obtaining the information.

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SPACE AIDS FOR MARINE NAVIGATION

Moscow KOSMICHESKIYE SREDSTVA SUDOVOZHDENIYA (Space Aids for Navigation) in Russian 1979 signed to press 25 Jul 78 pp 4, 286-287

[Annotation and table of contents from book by Yevgeniy Petrovich Churov and Yevgeniy Fedorovich Suvorov, Izdatel'stvo Transport, 1,600 copies, 287 pages]

[Text] Annotation. In this book the authors expound on the problems involved in the design, operation and utilization of satellite systems for marine navigation. They discuss the principles of the theory of space aids for navigation and give adequate descriptions of navigational earth satellites, ground complexes and the radio-navigation equipment carried on board ships. They also devote a great deal of attention to methods for determining location and correcting a ship's course and speed.

The techniques used to process navigational information and evaluate the accuracy of navigational observations are explained with the help of specific examples. There is also a brief discussion of questions relating to the geodetic use of navigation satellites.

This book is intended for scientific workers, navigators and other marine specialists who are concerned with research in navigation methods and equipment. It can also be of assistance to VUZ students and graduate students who are studying space aids and navigation complexes. Figures 89; references 52.

CONTENTS

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SPACE POLICY AND ADMINISTRATION

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NATURAL RESOURCES SATELLITE STUDY COMMISSION

Moscow ISSLEDOVANIYE ZEMLI IZ KOSMOSA in Russian No 2, 1980 pp 103-104

[Article by V. A. Ol'shevskiy: "USSR Academy of Sciences Commission for the Study of Natural Resources Using Space Equipment. Tasks, Structure and Scientific-Organizational Activity"]

[Text] The structure of the USSR Academy of Sciences commission for the study of natural resources using space equipment (the IPRZ commission) was changed in June of 1978 by a decree of the Presidium of the USSR Academy of Sciences, the scope of the commission's tasks was extended and new directions were formulated for the scientific and organizational activity. Vice President of the USSR Academy of Sciences, academician A.V. Sidorenko, was named chairman of the IPRZ commission. The commission includes scientists of the USSR Academy of Sciences and the academies of sciences of the union republics, as well as representatives of the ministries and departments participating in the development of the problem of earth studies from space and the implementation of their results in practice.

The primary tasks of the IPRZ commission are the coordination through the head institutes of individual aspects of the problem of scientific research, scientific procedure, experimental design and experimentation work to be performed within the framework of national programs, as well as the consideration of programs for international cooperation on the problem of earth study from space and the study of its natural resources and environment. The indicated problem includes the following basic approaches:

--The study and determination of the relationships of geological, geophysical and hydrological characteristics of ocean and dry land, as well as the physical parameters of the ocean and atmosphere to the characteristics of the earth's radiation field, which can be measured from space;

--The development and optimization of methods and principles for the design of the hardware for remote aerospace measurements;

--The development of the methods for topical interpretation of materials of earth photographs taken from space and the utilization of the information obtained for the solution of earth science problems;

--The introduction of methods of earth study from space, as well as the processing and interpretation of the information obtained into scientific research practice.

In accordance with the primary tasks assigned to it, the commission is defining the basic directions and tasks for scientific research on the problem of earth study from space, as well as the most efficient ways of developing the problem; the commission is hearing reports of the chief institutes on individual aspects of the problem, as well as those of the directors for scientific topics and projects, it is evaluating work results and making recommendations for the correction of research programs and plans; the commission approves summary and coordination plans for research on the problem of the study of natural resources of the earth from space and summary scientific reports on the work; it prepares proposals for drawing on new organizations of the USSR Academy of Sciences and the academies of sciences of the union republics for the execution of scientific research on the problem of earth study from space and the termination of unpromising research.

At the latest sessions of the IPRZ commission, in particular, reports were heard on the scientific and scientific-organizational activity dealing with the problem of earth study from space of the Space Research Institute of the USSR Academy of Sciences, the Institute of Geography of the USSR Academy of Sciences and the Geological Institute of the USSR Academy of Sciences; programs were considered and approved for scientific experiments to study natural resources, to be performed by international crews in orbital stations; scientific and engineering proposals for the further development of the methods and hardware for the study of natural resources of the earth from space vehicles were discussed; the results and further plans for work to be performed within the framework of the "Interkosmos" program is the field of earth study from space; the scientific program in the field of aerospace studies of the earth for the period from 1981 through 1990 was considered and approved.

The commission is composed of nine sections: the section of physical engineering and mathematical problems of earth study from space (the chairman is R.Z. Sagdeyev); the section on space geology (the chairman is academician A.V. Peyve); the section on space geography (the chairman is academician I.P. Gerasimov); the section on space oceanology (the chairman is corresponding member of the USSR Academy of Sciences A.S. Monin); the section on the utilization of space equipment for atmospheric study and pollution monitoring (the chairman is corresponding member of the USSR Academy of Sciences Yu.A. Izrael'); the section on the utilization of space equipment for agricultural purposes (the chairman is academician of the All-Union Academy of Agricultural Sciences imeni V.I. Lenin Yu.N. Fadeyev); the section on the study of water resources by means of space equipment (the chairman is corresponding member of the USSR Academy of Sciences, G.V. Voropayev); and the regional section on the study of the natural resources of Siberia using aerospace equipment (the chairman is academician A.L. Yanshin).

In 1979, scientific sessions, conferences and seminars were held in the sections of the IPRZ commission, in which questions of the utilization of aerospace information in the interests of geology, geography, agriculture and water management as well as protection of the environment were treated.

In particular, problems of the utilization of space photographs to solve problems of the geology of ore deposits were discussed in the section on space geology, and methods of remote geothermal prospecting for useful minerals were treated; questions of the evaluation of the status and dynamics of water objects, the spatial distribution of snow cover and the spread of pollution of surface and ground waters based on the data of aerospace photographs were discussed in the section for the study of water resources by means of space equipment. At a seminar organized by the section for the use of space equipment for agricultural purposes, primary attention was devoted to the questions of gathering, automated processing and topical interpretation of the information obtained from aircraft and space vehicles in different bands of the electromagnetic spectrum, for the purposes of evaluating the phyto-health status of agricultural resources and the appearance of negative situations in agricultural crops, determining soil moisture content in the surface layer, ascertaining the dynamics of water and wind erosion processes as well as determining the stages of the maturing of agricultural crops and working out the components of harvest yield forecasts.

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